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Proceedings Series 2001/25

Série des compte rendus 2001/25

Report of the PSARC Pelagic Subcommittee Meeting, August 29-30, 2001

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Pacific Scientific Advice Review Committee
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

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Canada

102-00753/

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PACIFIC SCIENTIFIC ADVICE REVIEW COMMITTEE

PSARC ADVISORY DOCUMENT 2001-5
SEPTEMBER 2001

PELAGIC

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SUMMARY

The Pacific Scientific Advice Review Committee (PSARC) Pelagic Subcommittee met August 29-30, 2001 in the Malaspina Room at the Coast Bastion Hotel in Nanaimo, B.C. The Subcommittee reviewed two Working Papers. External participants from First Nations, the fishing industry, and non-governmental organizations attended the meeting.

Stock Status and Recommended Yield

The five major herring stocks in B.C. are managed by a fixed harvest rate policy in conjunction with a Cutoff level. Cutoff levels are set at 25 percent of unfished average biomass. Yield recommendations are set at 20 percent of forecast annual biomass unless the forecast is close to or below Cutoff levels. For several years, the Subcommittee noted divergence of results between the age-structured model (ASM) and the escapement model (EM). To address the Subcommittee concerns a workshop was convened (June 12-14, 2001).

Assessments of major stocks in 2001 have been conducted using two versions of the age-structured model (ASM & RASM-2q) and the escapement model (EM). The alternative age-structured model formulation (RASM-2q) is a result of the discussions held at the workshop. While substantial progress has been made, there are still a number of unresolved issues that need further work.

For the five major stock assessment regions in B.C., the forecast biomass for 2002 is 199,040 tonnes. Application of the harvest policy results in a potential harvest of 38,950 tonnes for 2002.

Queen Charlotte Islands - The pre-fishery biomass forecast for 2002 at the 50% probability (i.e. 50% chance that the pre-fishery biomass will exceed this forecast) is 13,990 tonnes (50% CI: 12,280-17,610 tonnes) assuming average recruitment. At the 50% probability level, the forecast of returning biomass is above the Cutoff of 10,700 tonnes. Applying the decision rule results in a potential harvest of 2,800 tonnes.

Prince Rupert District – The pre-fishery biomass forecast for 2002 at the 50% probability is 34,130 tonnes (50% CI: 31,890-37,690 tonnes) assuming average recruitment. At the 50% probability level, the forecast of returning biomass is above the Cutoff of 12,100 tonnes. Application of the 20 percent harvest rate to the forecast results in a potential harvest of 6,830 tonnes.

Central Coast - The pre-fishery biomass forecast for 2002 at the 50% probability is 25,380 tonnes (50% CI: 23,650-29,730 tonnes) assuming average recruitment. At the 50% probability level, the forecast of returning biomass is well above the Cutoff of 17,600 tonnes. Application of the 20 percent harvest rate to the forecast results in a potential harvest of 5,080 tonnes.

Strait of Georgia - The pre-fishery biomass forecast for 2002 at the 50% probability (i.e. 50% chance that the pre-fishery biomass will exceed this forecast) is 103,100 tonnes (50% CI: 89,310-109,600 tonnes) assuming average-good recruitment. At the 50% probability level, the forecast of returning biomass is well above the Cutoff of 21,200 tonnes. Application of the 20 percent harvest rate to the forecast results in a potential harvest of 20,600 tonnes.

West Coast Vancouver Island - The pre-fishery biomass forecast for 2002 at the 50% probability (i.e. 50% chance that the pre-fishery biomass will exceed this forecast) is 22,440 tonnes (50% CI: 20,410-23,840 tonnes) assuming poor recruitment. At the 50% probability level, the forecast of returning biomass is just above the Cutoff of 18,800 tonnes. Applying the decision rule results in a potential harvest of 3,640.

Minor Stocks - The Subcommittee identified no potential harvest for Areas 27 and 2W.

Comments on Working Papers

Working Paper P2001-02: Stock assessment for British Columbia herring in 2001 and forecasts of the potential catch in 2002

The Subcommittee accepted the paper subject to revisions.

Working Paper P2001-03: An evaluation of a recruitment forecasting procedure for Strait of Georgia herring

The Subcommittee accepted the paper subject to revisions, but recommended that the recruitment forecast for the Strait of Georgia not be used for the 2002 forecast.

INTRODUCTION

The Subcommittee met on August 29-30, 2001 at the Coast Bastion Hotel in Nanaimo, B.C. to review the status of herring stocks in 2001 and to forecast abundance and potential harvest for 2002. The PSARC Chair opened the meeting, welcoming the participants. During the introductory remarks, the objectives of the meeting were reviewed, and the Subcommittee accepted the meeting agenda (Appendix 1). The Subcommittee reviewed two working papers (Appendix 2), and evaluated the impacts of pertinent assessment criteria (Appendices 4-8) in the formulation of advice to fisheries managers. The Subcommittee provided recommendations specific to the working papers in addition to general recommendations for further assessment work in support of management. Working paper titles, authors, and reviewers are listed in Appendix 2. A list of meeting participants is included as Appendix 3.

The Subcommittee evaluated a set of assessment indicators for each of the five major assessment regions. These criteria included:

- *Data quality*: catch data, spawn survey adequacy, consistency in age composition data;
- *Spawn and stock trends*: age-structured model and escapement model biomass estimates, spawn indices;
- *Perception of stock status*: based on charter skipper and district staff field observations;
- *Recruitment trends*: age-structured model estimates, auxiliary survey data;
- *Cutoff*: minimum spawning biomass level for stock conservation;
- *Forecast abundance (run size)*: for age-structured and escapement models, and evaluation of recruitment assumptions;
- *Additional information*: independent predictions of recruitment, size-at-age trends.

Subcommittee review of the assessment documents, in conjunction with the assessment criteria, was used to draw conclusions about the current biological status of the stocks and to provide yield recommendations for harvest in 2002. The following abbreviations are used throughout the Advisory Document:

ASM	Age-structured model
RASM	Revised ASM version 1
RASM-2q	Revised ASM version 2
EM	Escapement model
CC	Central Coast
FSC	Food, Social, Ceremonial
HCRS	Herring Conservation and Research Society
PR	Prince Rupert District
QCI	Queen Charlotte Islands
SG	Strait of Georgia
WCVI	West Coast Vancouver Island
CI	Confidence Interval
SOK	Spawn on Kelp

Stock status reports have been completed for each of the five major herring stocks and will be updated to reflect the 2001 fishery and assessment.

MANAGEMENT STRATEGY

Major Stocks

Five major British Columbia herring stocks are currently managed by a fixed harvest rate strategy in conjunction with a fishing threshold or "Cutoff" level. Potential harvest is calculated at 20 percent of the forecast biomass for each of the major assessment regions, provided that the potential harvest does not reduce the biomass below the Cutoff. The 20 percent harvest rate is considered to represent a conservative level of removals given the biological productivity of the major herring stocks. Cutoff levels are set at 25 percent of the estimated unfished average biomass, as determined by simulation analyses. As the forecast abundance approaches the Cutoff, the potential

harvest is calculated as the difference between the forecast abundance and the Cutoff. When the forecast falls below the Cutoff, a decision may be made to close the fishery to rebuild the stock. The objective of a Cutoff is to prevent relatively large fishery removals on stocks at low levels of abundance. This harvest strategy has been in place since 1983, prior to which the fishery was managed through a fixed escapement policy. A recent review (PSARC Working Paper H95-02) concluded that "*... the current management policy provides an adequate level of protection to conserve the stocks from a fishery collapse, and generates high long-term yields.*"

A summary of the performance of the forecasting procedure for 2001 herring fisheries is shown in Table 1, which compares the 2000 forecast of abundance in each stock assessment region to observed biomass in 2001 based on spawn surveys, catch, and model estimates. Note that all numbers were rounded to the nearest 100 tonnes after the requisite calculations.

Table 1 Comparison of 2000 PSARC forecasts of 2001 herring abundance with estimates of 2001 observed biomass, catch, and escapement (tonnes). The recruitment assumption that generated the forecast biomass (poor, average, good) and the observed recruitment category are shown in brackets. All numbers rounded to the nearest 100 tonnes.

Management Region	2000 Forecast of 2001 Biomass	2001 Observed Biomass	2001 Validated Roe Catch*	2001 Escapement
Queen Charlotte Islands	8,700 (average)	14,100 (average)	0	14,100
Prince Rupert	23,200 (average)	36,200 (good)	2,900	33,300
Central Coast	36,800 (average)	30,100 (poor)	6,100	24,000
Strait of Georgia	82,600 (average)	107,800 (average)	15,000	92,800
West Coast Vancouver Island	14,600 (poor)	13,600 (average)	0	13,600
Totals	165,900	201,800	24,000	177,800

*includes test fish catch

Minor Stocks

There are small or "minor" herring stocks that exist outside the five major stock assessment regions. The minor stocks are assessed opportunistically due to their inaccessibility, so the data series are not continuous or extensive. In its 1993 report, the PSARC Herring Subcommittee advised that there is no basis for fishing minor stocks above the 20 percent harvest rate established for the major stocks, and that the Department of Fisheries and Oceans should also protect a minimum spawning biomass for the minor stocks.

At the 1994 PSARC Herring meeting, the Subcommittee recommended that, because of incomplete historic data, minor stock harvests should be based on the estimated biomass of spawners in the previous season. Consequently, the Subcommittee recommended that the maximum biomass of fish harvested should not exceed 10 percent of the estimated previous season biomass. The recommended harvest rate for minor stocks is more conservative than the rate adopted for the major stocks; it is intended to compensate for the fact that minor stock survival and recruitment levels cannot be reliably predicted. The data do not allow accurate estimation of minor stock Cutoff levels. The Subcommittee advised that Fisheries and Oceans Canada should review biomass levels in light of available historic information prior to allocating minor stock harvests to clients. The Subcommittee noted that some minor stocks exhibit large fluctuations in abundance, therefore, the opportunity for harvest may not be available every year.

CATCH TRENDS

Herring in British Columbia waters have supported some form of commercial fishery since 1877. Reliable records of place, date, and quantity caught are available since 1950. A fishery for a dry salted market from 1904 to 1934 (with catches up to 85,000 tonnes annually) was followed by a reduction fishery (1935 to 1967). During the reduction, fishery catches were taken during the inshore spawning migrations from October to February. Very large catches (200,000 tonnes annually) in the early 1960s, in conjunction with a series of poor recruitments, led to the collapse of the reduction fishery and a subsequent closure in 1968. Cessation of the intensive reduction fishery allowed a gradual recovery of stocks. The roe herring fishery began in 1972. Herring are now caught on or near the spawning grounds by both purse seines and gillnets.

In 2001, there were 242 seine licenses eligible to fish. Another 10 licenses were retired temporarily in the test fishing program. There were 1,249 gillnet licenses eligible to fish after 7 licenses were retired temporarily for the test fishing program. Pool fishery management was continued in all roe seine and gillnet fisheries in 2001. Total roe landings in 2001 were 24,753 tons (22,456 tonnes).

The roe fishery first came under quota regulations in 1983. Prior to this, guidelines of anticipated roe catches were provided. The PSARC recommended yield, actual quota in the roe fishery, and roe catches (thousands of tonnes) since 1983 are listed in Table 2.

Table 2 Stock biomass forecast, recommended yield, actual roe fishery quota, and roe catches (tonnes x 1000) since 1984.

		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999[d]	2000[d]	2001[d]
QCI[f]	Forecast[a]				15.3	12.1	13.7	35.3	23.2	18.1	17.7	12.4	7.7	6.7	11.0	19.8	28.2	15.1	8.7
	Rec. Yield[b]				2.2	0.0	2.7	7.1	4.6	3.6	3.5	1.0	0.0	0.0	0.3	4.0	5.6	3.0	0.0
	Roe Quota	4.6	5.0	3.8	1.4	0.0	0.9	5.5	4.7	3.3	3.0	0.0	0.0	0.0	0.0	1.6	3.0	1.4	0.0
	Roe Catch[c]	5.0	6.3	3.6	2.0	0.3	1.4	9.0	7.0	3.8	4.0	0.3	0.0	0.0	0.0	1.4	3.0	1.8	0.0
PR	Forecast[a]				32.1	43.8	42.6	23.3	19.4	30.5	55.1	34.1	21.9	21.2	36.1	34.0	24.4	37.0	23.2
	Rec. Yield[b]				6.4	8.7	8.5	4.7	3.9	6.1	11	6.8	4.4	4.2	7.2	6.8	4.9	7.4	4.6
	Roe Quota	4.0	5.0	6.4	5.4	7.5	7.3	3.5	2.6	4.2	5.4	4.9	2.3	2.4	5.5	5.5	2.0	4.1	2.5
	Roe Catch[c]	3.5	6.5	8.3	6.1	7.9	8.5	4.9	3.5	5.0	6.3	4.7	2.1	3.1	5.5	3.2	2.1	4.3	2.9
CC	Forecast[a]				23.0	23.8	48.5	43.2	38.2	37.7	70.1	69.8	54.4	25.8	20.7	44.5	43.4	47.0	36.8
	Rec. Yield[b]				4.6	4.8	9.7	8.6	7.6	7.5	14.0	14.0	10.9	5.2	3.1	8.9	8.7	9.4	7.4
	Roe Quota	6.6	4.1	2.3	3.3	3.7	7.8	7.4	6.2	5.3	7.8	10.3	8.5	3.2	1.4	7.8	6.9	6.3	5.2
	Roe Catch[c]	7.2	5.2	3.3	3.6	4.5	9.5	8.4	8.9	8.3	10.5	11.9	9.6	4.3	3.6	8.6	7.5	7.4	6.1
SG	Forecast[a]				53.0	46.7	49.4	55.2	69.8	59.2	91.8	97.4	69.5	63.4	77.2	72.7	78.9	84.7	82.6
	Rec. Yield[b]				10.6	9.3	9.9	11.0	14.0	11.8	18.3	19.5	13.9	12.7	15.5	14.5	15.8	16.9	16.5
	Roe Quota	11.6	4.7	0.0	8.0	6.4	7.4	7.1	9.1	9.7	11.0	14.4	11.9	10.8	13.2	13.0	11.5	13.2	13.9
	Roe Catch[c]	10.2	6.2	0.2	9.1	7.5	7.4	7.9	10.6	12.5	13.1	16.7	12.5	13.6	15.4	12.7	11.8	14.0	15.0
WCVI[g]	Forecast[a]				48.3	39.6	52.6	35.9	33.9	29.1	NA[h]	36.3	20.8	21.4	24.1	40.1	39.6	21.5	14.6
	Rec. Yield[b]				9.7	7.9	10.5	7.2	6.8	5.8	3.4[h]	7.3	2.0	2.0	4.8	8.0	7.9	2.7	0.0
	Roe Quota	4.5		0.0	9.4	8.1	10.3	7.2	6.7	2.9	2.7	5.0	1.3	0.9	3.7	7.5	5.1	1.1	0.0
	Roe Catch[c]	6.7	0.2	0.2	15.9	9.7	13.4	9.9	8.6	3.7	5.6	6.0	2.0	0.8	6.7	7.0	4.4	1.6	0.0
Coast	Forecast	0.0	0.0	0.0	171.7	166.0	206.8	192.9	184.5	174.6	234.7	250.0	174.3	138.5	169.1	211.1	214.5	205.3	165.9
	Rec. Yield	0.0	0.0	0.0	33.5	30.7	41.3	38.6	36.9	34.8	50.2	48.6	31.2	24.1	30.9	42.2	42.9	39.4	28.5
	Roe Quota	31.3	18.8	12.5	27.5	25.7	33.7	30.7	29.3	25.4	29.9	34.6	24.0	17.3	23.8	35.4	28.5	26.1	21.6
	Roe Catch	32.6	24.4	15.6	36.7	29.9	40.2	40.1	38.6	33.3	39.5	39.6	26.1	21.8	31.1	32.9	28.8	29.1	24.0

[a] PSARC stock forecast used to derive recommended yield;

[b] PSARC recommended yield, includes allocations to non-roe fisheries;

[c] Roe catch includes all test fishery catches;

[d] Catch in 1999, 2000 qnd 2001 was the dockside validated catch;

[e] In 1983, the quota for North of Cape Caution was 11.8 tonnes;

[f] In 1983, 1985, 1990, 1991, 1992 and 1993 catch for QCI included both areas 2E and 2W;

[g] Includes Area 27 catch in 1983 & 1984 but excludes it in 1992, 1993, 1994, 1995 following removal from assessment region;

[h] No consensus on stock status, recommended that catch not exceed 1992 level.

STOCK STATUS AND FORECASTS FOR MAJOR ASSESSMENT REGIONS

Management Regions for Major Stocks

The stock assessment regions for major herring stocks are shown in Figure 1. For northern British Columbia, the stock assessment regions used for the 2001 assessments are the same as those used in previous years. In the Queen Charlotte Islands (QCI), the assessment region extends from Cumshewa Inlet in the north to Louscoone Inlet in the south. The Prince Rupert District (PR) stock assessment region includes all of Statistical Areas 3 to 5. The Central Coast (CC) assessment region encompasses Area 7, Kitasu Bay in Area 6, and Kwakshua Channel in Area 8. As recommended by the Herring PSARC Subcommittee in 1991, the Strait of Georgia (SG) is considered a single stock complex which includes Deepwater Bay and Okisollo Channel in Area 13 and all of Areas 14 to 19, 28 and 29. In 1993, the northern (Area 25) and southern (Area 23/24) Statistical Areas were combined into the West Coast Vancouver Island (WCVI) assessment region.

Stock Assessment

Traditionally, two analytical stock assessment models, an age-structured model (ASM) and an escapement model (EM) have been applied to each management region. For several years, the Subcommittee noted divergence of results between the ASM and the EM. To address the Subcommittee concerns a workshop (Appendix 9) was convened (June 12-14, 2001) to:

- identify and attempt to resolve deficiencies in the current ASM;
- review the existing fishery and biological data for herring and associated assumptions; and
- review the statistical aspects of the ASM and the associated assumptions; and survey alternative model formulations and inherent assumptions.

Assessments of major stocks in 2001 have been conducted using two new versions of the previously used age-structured model (ASM) and the escapement model (EM). The new versions of the age-structured model (RASM and RASM-2q) are the result of discussions held at the workshop. The RASM and RASM-2q include the following modifications:

- removal of sample size adjustment based on between sample variance (both);
- increase in penalty weight for spawn data from 10 to 50 (both); and
- fixing of the dive survey spawn conversion parameter at 1.0 (RASM-2q only).

While substantial progress has been made, there are still a number of unresolved issues that need further work.

The potential recruitment of age 2+ fish to each stock is calculated for each model as the mean of the top one-third, middle one-third, and bottom one-third of the recruitment estimates from the 1951 to 2001 time series for the age-structured models. In the absence of additional information to forecast recruitment, the average recruitment forecast is used. Recruitment is added to the expected age 3+ and older abundance to obtain the forecast abundance. The potential harvest is calculated as 20 percent of the forecast abundance. If this yield would reduce the escapement biomass of a stock below the Cutoff, the potential harvest is calculated from the following equation:

Potential Harvest = Forecast - Cutoff

Thus, progressively smaller potential harvests are identified when a stock approaches its Cutoff level. The Cutoff is calculated independently for each stock assessment region.

An example of potential harvest (yield) calculations for three levels of forecast biomass is shown in Figure 2. The Cutoff for this example is set at 10,000 tonnes (dashed vertical lines). The upper panel shows catch (tonnes) as a function of the forecast biomass, while the lower panel shows harvest rate as a function of the forecast biomass. There are three scenarios denoted by A, B, and C on the figure panels:

(A) The forecast biomass of 7,500 tonnes is below the Cutoff, so the potential harvest is 0, and the harvest rate is 0.
(B) If the 20 percent harvest rate was applied, the forecast biomass of 11,000 tonnes would yield 0.2*11,000=2,200 tonnes. However, this yield would bring the stock size below the Cutoff value to 11,000-2,200=8,800 tonnes. Thus, the potential harvest is 11,000-10,000=1,000 tonnes. This is equivalent to a harvest rate of 1,000/11,000=0.09, a value roughly half that of the rate of 0.2 used at higher levels of biomass.
(C) The forecast biomass of 20,000 tonnes is well above the Cutoff, so the potential harvest is 0.2*20,000=4,000 tonnes.

Potential Coast-Wide Harvest for 2002

The recruitment assumption, corresponding 2002 pre-fishery biomass forecast, and the potential harvest for each of the major stock regions are listed in Table 3. The spawning stock biomass trends based on the age-structured model (RASM), the revised age-structured model (RASM-2q) and escapement model (EM) are shown in Figures 3 and 4 respectively. These trends were interpreted in light of the assessment criteria listed in Appendices 4-8 for each management region to determine the potential harvest. Regional synopses are provided below. The Subcommittee noted that the total potential harvest of approximately 38,950 tonnes for 2002 is a 37 percent increase from the total recommended potential harvest of 28,500 tonnes in 2001.

Table 3 Potential Harvest in 2002 for Major Herring Stocks

Assessment Region	Cutoff Biomass (tonnes)	Recruitment Assumption	Forecast Biomass (tonnes)	Potential Harvest (tonnes)
Queen Charlotte Islands	10,700	Average	13,990	2,800
Prince Rupert District	12,100	Average	34,130	6,830
Central Coast	17,600	Average	25,380	5,080
Strait of Georgia	21,200	Average-Good	103,100	20,600
West Coast Vancouver Island	18,800	Poor	22,440	3,640
Total			199,040	38,950

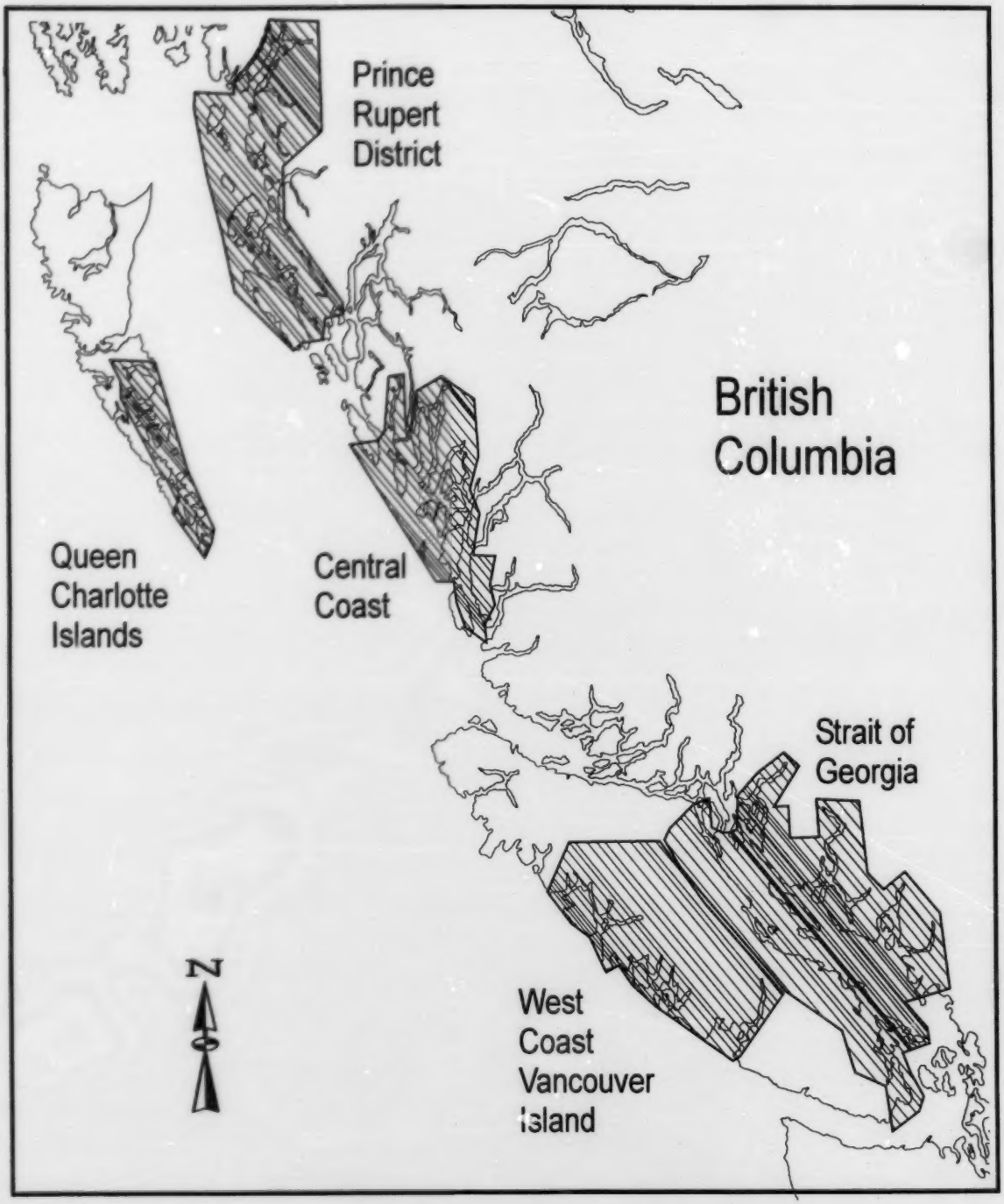

Figure 1. Herring stock assessment regions in British Columbia.

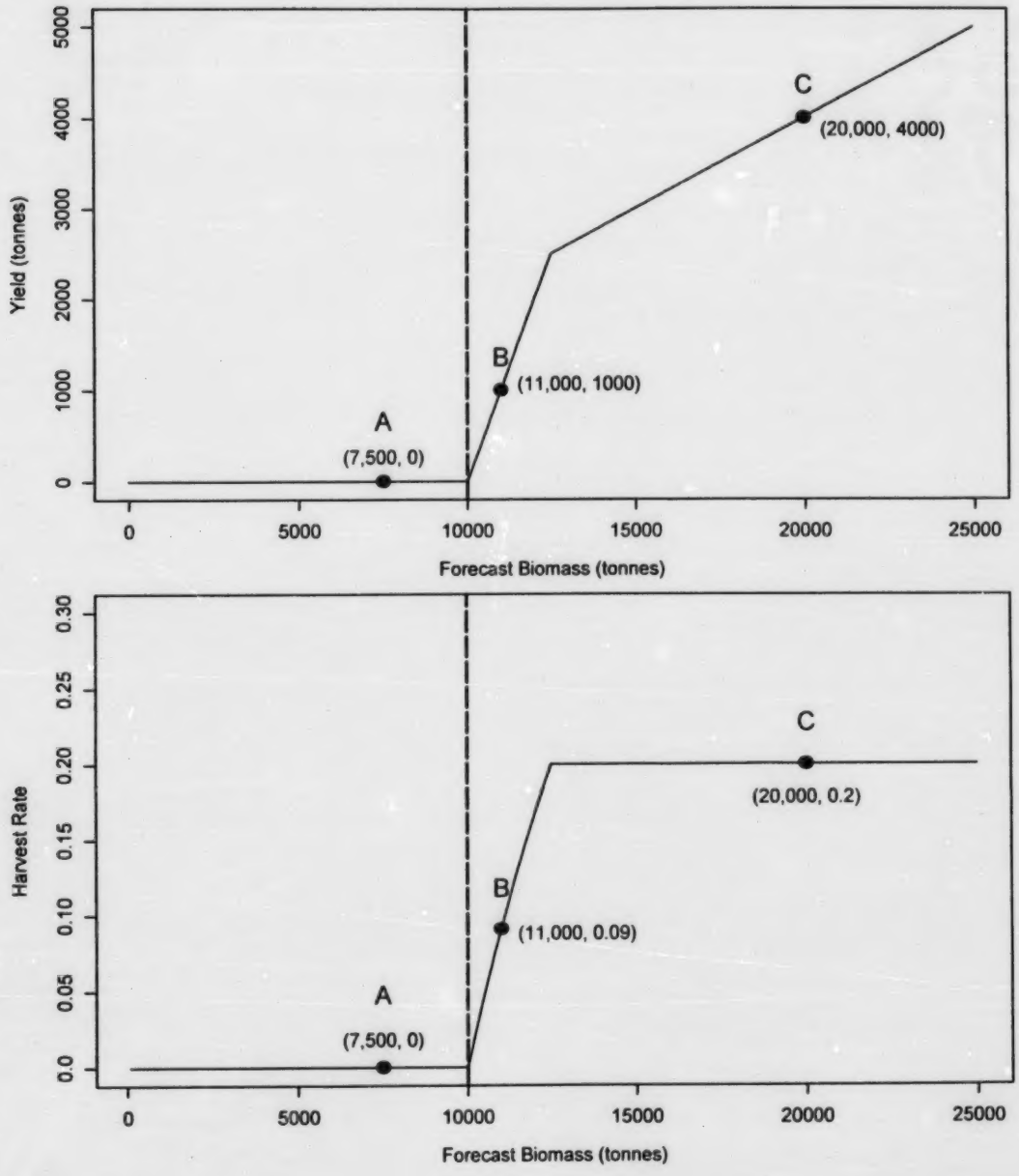

Figure 2. Examples of yield and harvest rate at three different levels of forecast biomass. The letters A, B, and C denote three harvest scenarios as described in the text.

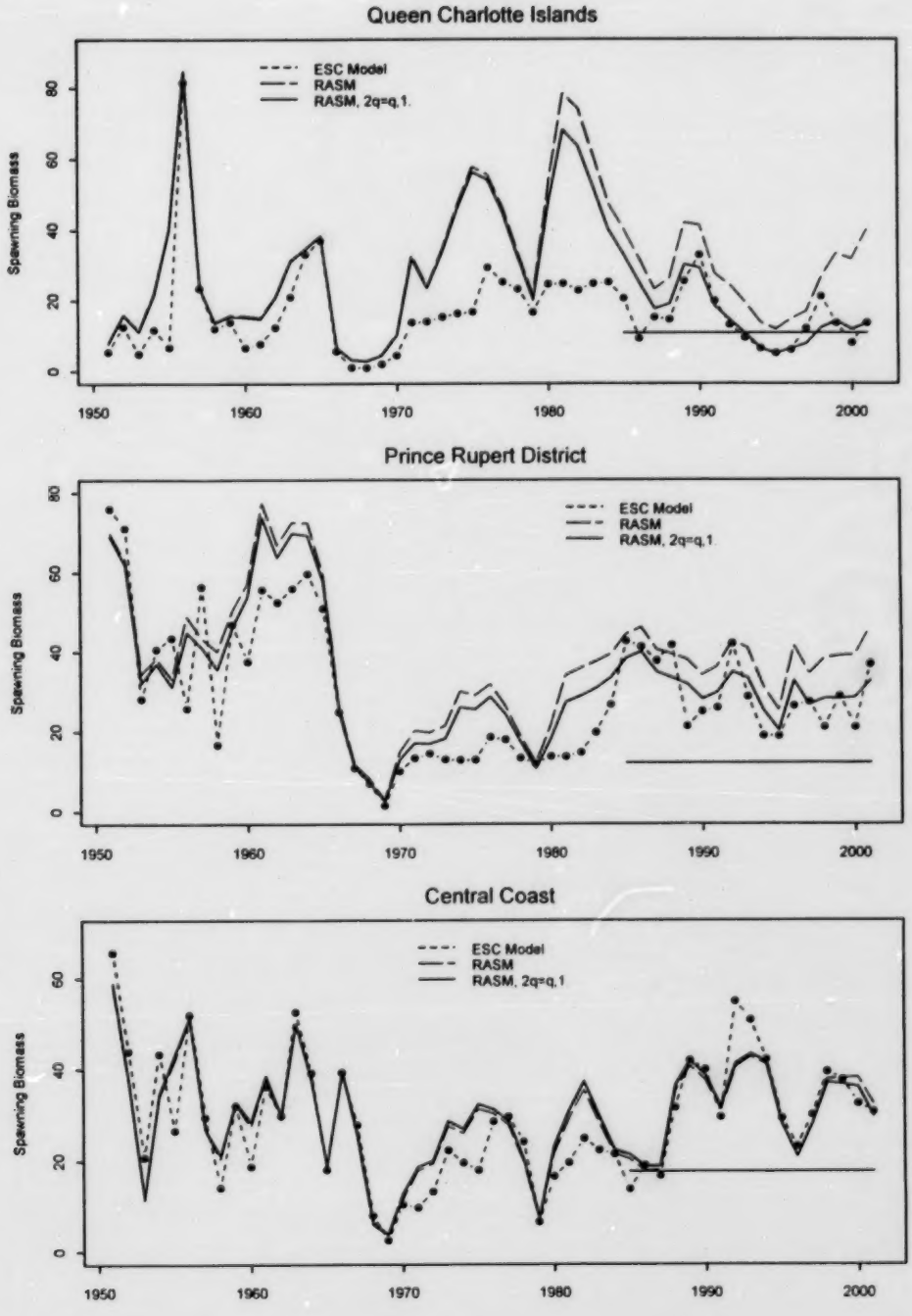

Figure 3. Estimates of pre-fishery spawning stock biomass (tonnes x 1000) from age-structured (RASM and RASM-2q) and escapement model (EM) analyses for northern B.C. herring stock assessment regions, 1951-2001. Horizontal line indicates the Cutoff level for each stock.

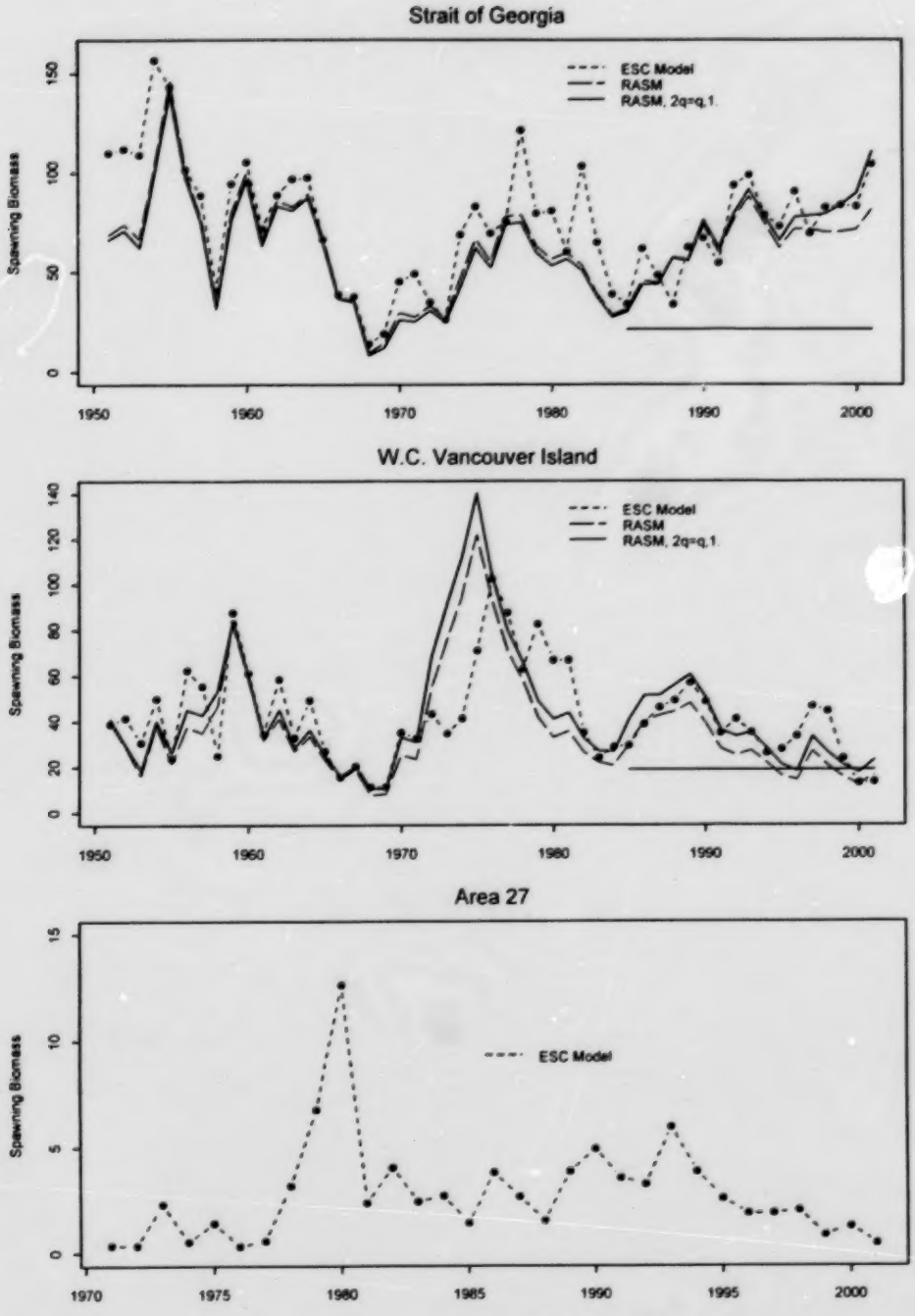

Figure 4. Estimates of pre-fishery spawning stock biomass (tonnes x 1000) from age-structured (RASM and RASM-2q) and escapement model (EM) analyses for southern B.C. herring stock assessment regions and Area 27, 1951-2001. Horizontal line indicates the Cutoff level for each stock.

Queen Charlotte Islands

Background

Landings during the reduction fishery period (1951 to 1968) were highly variable, targeting on a few strong year classes. The maximum catch taken during this period was over 77,000 tonnes; however, there were 6 years when catches were less than 1,000 tonnes. Catches have been more stable since the beginning of the roe fishery and have generally been in the range of 4,000 to 8,000 tonnes. The area was closed to roe herring fisheries in 1988 due to stock concerns. The stock recovered after the closure but declined from 1990 to 1995. In response to the observed decline, annual roe fishery catches were reduced from 7,800 tonnes in 1990 to 2,700 tonnes in 1993. In 1994, the forecast return was close to Cutoff, and fishing was restricted to Food, Social and Ceremonial (FSC) harvest and spawn-on-kelp only. For 1995 and 1996, the forecast abundance was below Cutoff so fishing was limited to FSC harvest only. In 1997, FSC harvest was permitted, and three spawn on kelp operators used a maximum of 150 tonnes of herring to obtain their quota. The roe fishery was re-opened in 1998, with a harvest of 1,400 tonnes. In 1999 and 2000 roe harvests of 3,000 and 1,800 tonnes were removed. The stock was below Cutoff again in 2001 so no roe fishery was permitted but a restricted SOK fishery using open ponding occurred.

Assessment Criteria

The only fisheries in 2001 were SOK and FSC. No catch was reported for the FSC fishery. All spawning was surveyed and was more extensive than last year. Sampling coverage was adequate but a number of sets were not sampled due to the presence of large numbers of very small fish. All indices and assessment models indicate that abundance has increased significantly from 2000. Charter skipper and managers feel that stocks have increased but that a 2002 fishery may be premature. Recruitment of the 1997 and 1998 year-classes has been average and indications are that the 1999 year-class will be average.

The Subcommittee adopted the RASM-2q model, and chose average recruitment. The pre-fishery biomass forecast for 2002 at the 50% probability (i.e. 50% chance that the pre-fishery biomass will exceed this forecast) is 13,990 tonnes (50% CI: 12,280-17,610 tonnes). At the 50% probability level, the forecast of returning biomass is above the Cutoff of 10,700 tonnes. Application of the decision rule (0.2*Forecast biomass) results in a potential harvest of 2,800 tonnes. The Subcommittee recommended caution be excercised when setting a harvest for this area because the area was closed in 2000, and the stock is rebuilding.

Prince Rupert District

Background

During the period of the reduction fisheries, herring catches in the Prince Rupert District were generally in the range of 10,000 to 50,000 tonnes annually. Since the beginning of the roe herring fishery, catches have averaged 5,000 tonnes and have not exceeded 9,000 tonnes. Since 1972, the fishery was closed only in 1983. The area has supported substantial roe herring and spawn-on-kelp fisheries in recent years. However, there was no seine fishery carried out in the traditional location (Kitkatla Inlet) from 1996 to 1999 because spawning biomass had declined. In 1998 and 1999 spawn distribution returned to a more normal pattern. A modest roe fishery of 4,300 tonnes occurred in the area in 2000 and 1,900 tonnes in 2001.

Assessment Criteria

The FSC catch reported in the Prince Rupert District was incomplete. All major spawns were surveyed. In-season and stock sampling and spawn assessments programs were carried out in a manner considered acceptable for stock assessment purposes. Biological samples were obtained from all fisheries. Management staff felt Kitkatla stocks and Big Bay stocks appear strong and test fishing skippers felt that the spawn biomass in Kitkatla had shifted south, but had increased.

The EM and RASM-2q models both indicate a substantial increase in abundance in 2001. There was an increase in size-at-age, spawn length, width, average number of egg layers and subsequently in spawn biomass. This area has been on an increasing trend since 1998. The recruitment time series indicates an average or above average recruitment in 3 of the last 4 years.

The Subcommittee adopted the RASM-2q estimate, and average recruitment was chosen. The pre-fishery biomass forecast for 2002 is 34,130 tonnes (50% CI: 31,890-37,690 tonnes). The forecast of returning biomass is above the Cutoff of 12,100 tonnes. Applying the decision rule of a 20% harvest rate results in a potential harvest of 6,830 tonnes.

Central Coast

Background

Landings during the reduction fishery period (1950-1968) ranged to just over 44,000 tonnes and were generally around 10,000 to 35,000 tonnes. During the subsequent roe fishery period (1972 to present), landings have averaged 7,145 tonnes and reached a maximum of 14,000 tonnes in 1978. No harvest was permitted in the Central Coast in 1979, but fisheries have occurred annually since that time. Harvests were approximately 10,000 tonnes from 1993-1995, then were reduced to 3,200 tonnes in 1996 in response to declining abundance. Abundance increased dramatically over the following three

years as a result of good 1994 and 1995 year-classes. However, abundance has declined over the last three years with a harvest of 5,600 tonnes in 2001.

Assessment Criteria

FSC catch reporting was incomplete for the Central Coast. In-season stock sampling and spawn assessment programs were carried out in a manner considered acceptable for stock assessment purposes. Biological samples were obtained from all fisheries. Management staff felt that there was an overall decrease of stock from previous years. It was also noted that the total area of spawn had contracted relative to recent years. Test fishing skippers felt that in general stocks and spawn seemed to be similar to last year.

Both stock assessment models showed a small decline in stock abundance since 1998. There was a slight decrease in spawn length, width and a decrease in egg layers in 2001. RASM-2q estimates of recruitment indicate that the last three year-classes have been average or less than average. The RASM-2q projection suggests that recruitment in 2002 could also be below average. The Subcommittee felt there was insufficient evidence to support poor recruitment and adopted the average recruitment scenario. The retrospective analysis of the RASM-2q model in this region indicated a consistent pattern over time.

The Subcommittee adopted the RASM-2q and chose average recruitment. Pre-fishery biomass forecast for 2002 at the 50% probability is 25,380 tonnes (50% CI: 23,650 – 29,730 tonnes). At the 50% probability level, the forecast of returning biomass is well above the Cutoff of 17,600 tonnes. Applying the decision rule of a 20% harvest rate results in a potential harvest of 5,080 tonnes.

Strait of Georgia

Background

Annual herring landings from the Strait of Georgia during the reduction fishery period (1951 to 1968) were less variable than from other areas of the coast. With the exception of the 1952/53 season when industry disputes curtailed the herring fishery, and the 1967/68 season when stocks had collapsed, landings ranged from 31,000 tonnes (1966/67) to 72,000 tonnes (1955/56). During the period of roe herring fisheries, catches have averaged 11,600 tonnes. The area was closed to roe herring fishing in 1986, after which time harvests have increased to a peak of 16,304 tonnes in 1997 and a catch of 13,604 tonnes in 1998. The high catches in the 1990s have been supported by near record high stock abundance in the Strait of Georgia. A harvest of 14,200 tonnes occurred in 2001.

Assessment Criteria

All catch was reported, and all known spawns were surveyed. In 2001, spawns occurred in a largely similar distribution to other years, as well as in a number of "non-traditional"

areas: Lasqueti Island, Texada Island, and Saanich Inlet. Overall, there was a slight decrease in the number of layers of eggs deposited in 2001, but the length of spawn increased. In-season stock sampling and spawn assessment programs were carried out in a manner considered acceptable for stock assessment purposes. Biological samples were obtained from all fisheries. Management staff and test fishing skippers felt that stocks continued to look very healthy.

All models indicate a long term trend of increasing abundance since 1985, and that this stock is approaching historical high levels. During the past decade 9 of 10 year-classes have been average or better. There is a suggestion of variability and slight over-forecasting in the retrospective RASM-2q analysis. Based on the likelihood profile of the RASM-2q model average recruitment is projected for 2002. However, the Subcommittee noted that a series of strong recruiting year-classes have been observed in recent years.

The Subcommittee had considerable discussion about the merits of the RASM-2q and EM models. The Subcommittee noted that there was no compelling reason to choose one model over the other, especially since the forecasts from both models were quite similar. The Subcommittee eventually adopted the RASM-2q model, and chose an "average to good" recruitment forecast because of the observation that recent year-class strength has been average or better.

The pre-fishery biomass forecast for 2002 at the 50% probability (i.e. 50% chance that the pre-fishery biomass will exceed this forecast) is 103,100 tonnes (50% CI: 89,310 – 109,600 tonnes). At the 50% probability level, the forecast of returning biomass is well above the Cutoff of 21,200 tonnes. Applying the decision rule of a 20% harvest rate results in a potential harvest of 20,600 tonnes.

West Coast Vancouver Island

Background

During the period of the reduction fishery, catches from the West Coast of Vancouver Island reached nearly 70,000 tonnes in the 1958/59 season. In general, catches were in the range of 10,000 to 25,000 tonnes. During this period, annual harvests in the southern region (Area 23/24) exceeded harvests in the north (Area 25) for all but three years (51/52, 59/60, 62/63), often by large amounts. Since the roe fishery began in 1972, catches have been below the earlier levels, except from 1975 to 1978, when they ranged from 26,000 to 39,000 tonnes. In 1985 and 1986, the commercial fishery was closed along the entire west coast of Vancouver Island due to low stock abundance. The stock subsequently increased and the 1987 harvest of nearly 16,000 tonnes was the largest since 1979. Abundance has declined since 1989. Catches have averaged 5,400 tonnes since 1990 compared to an average harvest of 22,200 tonnes prior to 1980. Effort was restricted in 1995 and 1996 since forecast abundance was marginally above Cutoff in both years. Abundance peaked again in 1997 with the appearance of a strong 1994 year-class but has declined since then. A small harvest of 1,600 tonnes was taken in 2000 but only SOK fisheries were permitted in 2001.

Assessment Criteria

FSC catch was incomplete with no information coming from the Nuu-chah-nulth Tribal Council. There were some estimates of FSC catch from test boats and spawn on kelp observers. Spawn surveys were complete for all major spawn locations with some minor spawn missed in Area 26 and Area 27. Spawn indices indicated a decrease in length and width of spawn. The percent cover was similar to last year and the average layers of eggs increased from 2000. Biological sample coverage was good. Test fishing skippers commented that Esperanza Inlet looked better in 2001 than in 2000, but Nootka Sound was poorer. Managers noted that Sydney Inlet and McKay Island had good spawns, and that spawns in Hesquiat were disappointing.

Abundance in the WCVI assessment region remains depressed. The stock assessment from the EM model was similar to 2000 while the RASM -2q model showed a slight increase. In terms of recruitment the last good year class was 1994 with the 1995-1997 year-classes being poor. The recruiting 1998 year class is average. The cumulative probability plot for the EM model indicates that there is a 30% chance that abundance in 2002 could be below the Cutoff. The recruitment forecast from the 2001 offshore cruise indicates poor recruitment for 2002.

The Subcommittee adopted the RASM-2q model forecast, and chose the poor recruitment assumption. The pre-fishery biomass forecast for 2002 at the 50% probability (i.e. 50% chance that the pre-fishery biomass will exceed this forecast) is 22,440 tonnes (50% CI: 20,410 – 23,840 tonnes). At the 50% probability level, the forecast of returning biomass is only marginally above the Cutoff of 18,800 tonnes. Applying the decision rule results in a potential harvest of 3,640 tonnes (Forecast biomass – Cutoff). The Subcommittee also recommended that extreme caution be exercised when setting a harvest for this area because of the area closure during the past two years.

Minor Stocks

Spawn dive surveys were complete in Winter Harbour and spawn was reported to be poor with coverage very patchy. Some spawn around Mayday Island in Klaskino Sound was not surveyed and there may have been spawn in Klaskish Inlet that was missed.

Based on the estimated spawning biomass of 273 tonnes for this area the Subcommittee could not recommend any harvest for 2002.

There was no potential harvest identified for 2002 for Area 2W because of the paucity of historic and recent spawn data, biological sampling and acoustic soundings.

STOCK ASSESSMENT WORKING PAPERS

This section presents a summary of working papers and corresponding reviews. Subcommittee discussion is recorded, along with recommendations for revision of each working paper and directions for future analyses. General recommendations from the Subcommittee appear later in the report.

P2001-02 Stock assessment for British Columbia herring in 2001 and forecasts of the potential catch in 2002

J. Schweigert ** Accepted with revisions **

Summary

The 2001 herring stock assessments use two analytical models (explicitly developed for British Columbia herring): (1) a modification of the escapement model (EM) described by Schweigert and Stocker (1988); and (2) a modification of the age-structured model (RASM) described by Fournier and Archibald (1982). In addition, a third analytical model a variation on the age-structured model (RASM-2q) assuming different spawn conversion parameters for surface and diver spawn survey eras, is developed. All models reconstruct stock abundance for the period 1951-2001 and forecast pre-spawning abundance for the 2002 season. Forecasts run size for 2002 are based on the combination of estimates of surviving repeat spawners and newly recruiting spawners which are presented as poor, average, and good, based on historic recruitment levels. Coastwide, abundance increased in 2001 with the recruitment of an average to above average 1998 year-class in most areas. Forecasts for 2002 generally indicate run sizes similar to or greater than those observed in 2001.

The presentation of the assessment focussed on investigations of new parameterizations for the spawn conversion parameter (q) and other factors discussed at the recent herring workshop (see Appendix 9). Fixing the q parameter equal to 1.0 for the dive survey era and estimating q for the surface survey era resulted in a good fit to the spawn index data for all areas. An additional change in the model parameterization has been to increase the weighting on the spawn index data.

Reviewers' Comments

Reviewer 1 noted that the data and methods described in the working paper are adequate to provide abundance forecast for 2002. However, this reviewer stated that it was not clear how the cumulative probability distributions of forecast spawning biomass was derived for the escapement model. Estimation and forecasting of spawning stock biomass are very sensitive to the *q* value. To address this, reviewer 1 recommended field sampling research to get some actual measure of *q*. This reviewer noted that the paper has not mentioned any environmental variability, which can be very important for

forage species such as herring. Some review on the population status of its predator species and other physical oceanography factors may be helpful to foresee potential changes in the herring stock.

Reviewer 2 concluded that the purpose of the paper is clearly stated. The methods are adequate to support and evaluate the conclusions. Reviewer 2 noted that the age-structured (AS) model has been used since 1982, and it can still be regarded to be in the vanguard of modern stock assessment procedures. Nonetheless, the reviewer felt that the document does not explain in sufficient detail alternative scenarios to evaluate the abundance forecasts. Nor are there explicit procedures to evaluate and determine quotas that incorporate the uncertainty in the data and fishing power. His major concerns relate to the form of documentation and review for the assessment procedure and evaluation of the modifications made to the AS model.

Subcommittee Discussion

The author gave the Subcommittee a brief overview of the results of the Herring Workshop (Appendix 9), which PSARC requested last year. DFO and external Workshop participants commented that the technical review was extremely useful in clarifying some assumptions and weaknesses in the assessment models. The Subcommittee commended Mr. Schweigert for organising the Workshop.

The new RASM-2q model appears to represent a significant improvement over previous versions. The Subcommittee recognized that the two models are not independent, because the RASM-2q version uses output from the escapement model as an index of spawner biomass. The Subcommittee discussion focussed on the fact that both models are useful tools because they have a slightly different perspective on the status of the stocks. Conceptually, the ASM has the capacity to incorporate much more data and make realistic assumptions about these data and in this regard appears to be superior to the escapement model. Also, the age-structured model has the capacity to do a better job of quantifying the uncertainty in the data. However, the point was raised that both the EM and the RASM-2q models could produce a somewhat lower estimate of the actual biomass of spawners, because some spawns will be missed, and because some egg mortality occurs before the spawns are surveyed. It was also noted that in four of the five stock assessment regions the RASM-2q model produced lower estimates of stock abundance than the EM.

The Subcommittee recommended that more biological research and technical evaluation are required to confirm that the age-structured model is the best of the alternatives. The Subcommittee also noted that objective criteria need to be devised to evaluate the performance of alternative models.

The Subcommittee discussed some potential problems with the data used by the assessment models. It was noted that the age-structured model analysis combines samples from the test fishery and the roe seine fishery – but conceptually, the model should rely only on catch samples. The Subcommittee discussed the possibility that

since the test fishery samples a much broader distribution of the stock these samples may not be representative of the commercial seine catch, which is usually removed from a smaller area, which could have a different age composition. More analysis is required to show that the test fishery samples can be used as representative of the commercial catch, and that no bias in the stock assessment is being introduced by using the test fishery data. The Subcommittee requested this analysis for next year. The adequacy of the 2001 spawn survey was discussed and it was noted that all major spawns were adequately covered. Some Subcommittee members remained unconvinced, however, that the survey effort is adequate or defensible, given the importance of the results to the assessment of herring.

One of the external referees commented that the stock assessment document is too large, and recommended that the document be either broken into a methods document and an assessment document or be reviewed as a whole less frequently. The Subcommittee suggested that the methods document would only need to be reviewed when there were significant changes in model formulation. Following current practice, the assessment document would need to be reviewed annually, so the Subcommittee could discuss the annual assessment, the data quality and assumptions behind the stock projections.

After extensive discussion on the model choice for the 2002 forecast, the Subcommittee chose to adopt the RASM-2q model, even though this choice was not unanimous. The Subcommittee agreed that until there is clear evidence that the age-structured model provides a better estimate of stock abundance than the escapement model, both models should be evaluated on a stock by stock basis.

Subcommittee Recommendations

1. The Subcommittee accepted the paper, with the revisions requested by the external reviewers, and by the Subcommittee members.
2. The Subcommittee requested that objective criteria be developed for evaluating the performance of alternative models.
3. To improve the age-structured model, the Subcommittee requested that existing information on B.C. and Alaska herring egg loss rates and other relevant information be used to come up with a prior distribution for the q parameter. This review work should precede any field research initiatives.
4. The Subcommittee agreed that the model formulation does not necessarily need to be reviewed annually, but only when significant changes occur.
5. Subcommittee endorsed the recommendations from the herring workshop (see Appendix 9).

P2001-03 An evaluation of a recruitment forecasting procedure for Strait of Georgia herring

R. Tanasichuk ** Accepted with major revisions**

Summary

This report describes an evaluation of an extension of the recruitment forecasting procedure which has been used since 1987 to forecast recruitment (number of age 3 spawners) for the West Coast Vancouver Island (WCVI) stock of Pacific herring (*Clupea pallasi*). The extension is to forecast recruitment for Strait of Georgia herring. The forecasting procedure is based on the age composition of samples of herring trawled along the southwest coast of Vancouver Island during summer fisheries oceanography surveys. Results of analyses of data on proportion of age 3 fish showed that proportion of age 3 fish from the WCVI and Strait of Georgia stocks were correlated significantly and that the functional relationship had a slope and intercept which were not significantly different from 1 and 0 respectively. Therefore, the year-specific proportion at age 3 was the same for both stocks which means that proportion at age 3 for either stock should not be biased by mixing on the summer feeding grounds. Results of regression analyses showed that interannual variations in proportion of age 3 fish observed in the prefishery can be predicted from the proportion of age 3 herring in the samples trawled the previous summer. Results of analyses-of-covariance showed that there was no significant effect of stock on the slopes or intercepts of the predictive regressions for the escapement and age-structured assessment models estimates of proportion of age 3 fish. Residual analysis of the pooled regressions showed no time trend in the residuals, nor any effect of sampling time or the magnitude of the forecast. A retrospective analysis of the forecasts over 1997 – 2001 showed that observed proportions at age 3 were mostly within the 95% confidence interval of the forecast, and that the mean difference between forecasted and observed proportion at age 3 was 0.05. The approach provides acceptably accurate forecasts of recruitment for the Strait of Georgia stock. Recruit biomass forecasts with 95% confidence limits are given for the three stock assessment models.

Reviewers' Comments

Reviewer 1 thought the paper was useful but in need of revision to clarify parts of the methods and assumptions. Specifically, the objectives of the paper require clarification. Reviewer 1 suggested that some further biological discussion and explanation of the assumptions, including implications about stock mixing on feeding areas is necessary.

Reviewer 1 also was concerned about reliability of historical data and whether the author used the correct models - specifically the correspondence between proportion of age 3 herring (P3) on WCVI and SG. There also were some concerns about statistical methods. Reviewer 1 indicated that the recommendations to management need clarification.

The main concerns of reviewer 2 were mainly about statistical methods and the structure of the paper. Reviewer 2 questioned whether two separate regressions (one each of SG and WCVI) were appropriate, because P3 values from SG and WCVI were not independent. The main editorial comments were concerned with the presentation of the paper. Specifically, reviewer 2 concluded that the Introduction was not adequate to explain the purpose and content of the paper, and some parts of the Methods section were either incompletely or inadequately explained.

Additional critical comments were provided in the meeting by a co-reviewer working with reviewer 2. Two main additional points were that the assumption of similar P3 estimates from SG and WCVI were not supported from the data. Second, there is little discussion of the accuracy of the models. Noting the scatter of the points, the reviewer suggested that the predicted proportion of recruits can range between 0.21 and 0.67, and then asks if such a wide estimate would be useful.

Subcommittee Discussion

The Subcommittee raised many questions about this paper and identified a number of deficiencies. The Subcommittee questioned the small sample size from which proportion of age 3 recruits (P3) are forecast. Specifically, the question of whether it was justified to estimate P3 from only 3 tows of the survey arose. The justification given was that since these are all the available data we have, then we should use them. The Subcommittee also noted that analyses of previous years have used even fewer data points. Other members wondered about the impact of a few data points on the left side of the histograms (small size at age 2+) and suggested that there could be a big impact from outliers.

The Subcommittee pointed out that there are irregular patterns in the residuals of the forecast regression. To address this issue the author is advised to include additional terms in the regression equations. The Subcommittee also noted that the retrospective analysis was too optimistic because it did not include uncertainty about weight-at-age and biomass.

Some Subcommittee members were not able to understand how the estimation of the proportion of age 3 fish from the same offshore area, and without identification of the origins of these fish, could support a prediction of good recruitment for the Strait of Georgia and poor recruitment to the West Coast of Vancouver Island.

The Subcommittee asked what could determine the nature of coherence in herring year-class strength (P3) - and noted that moderate coherence of strong year classes has been observed through many areas of the B.C. coast, and along the Pacific coast - for herring and other species.

The Subcommittee also noted that the author's 2000 presentation predicted that the recruitment of Strait of Georgia herring in 2001 would be very low, whereas it was observed to be very high in 2001. In reply, the author suggested that the prediction in

2000 was indeed an error, because of problems caused by the inappropriate application of the age-length key. The author showed this problem has been solved in 2001 by use of age determinations using scales.

The Subcommittee accepted the paper subject to major revisions, and specifically with the understanding that the paper represents work in progress. The recruitment predictions for the WCVI can be considered for the 2002 abundance forecast, but the predictions should not be used for SG without further evaluation and analysis. Further, it is essential to make predictions as poor, average or good recruitment, although the Subcommittee recognized that the work could develop, in the future from there to possible more explicit estimates.

Subcommittee Recommendations

1. The Subcommittee accepted the paper subject to major revisions, but not the Strait of Georgia recruitment forecast.
2. The Subcommittee asked that prediction of year-class strength be presented in the form of 3 categories (poor, average good) that are presently used in the assessments.
3. The Subcommittee recommended the submission of a paper on the same topic in 2002.

OTHER REPORTS

A review of 2000/2001 British Columbia Herring Fisheries

L. Hamer and J. Hepples

A draft version of "A Review of 2000 / 2001 British Columbia Herring Fisheries" was distributed. In this report, 2000 PSARC stock assessment results and forecasts are briefly summarised, and allocations to all 2000 / 2001 herring fisheries are documented. Management structures of the various fisheries are described, and catch information is presented. Sections documenting the dates and locations for roe herring fisheries, winter food and bait fisheries, and test fisheries are also included. Additionally, the 2001 spawn report is tabled. This fishery review will be posted on the DFO web page when it is finalized.

Report of the BC Herring Stock Assessment Review Workshop, June 12-14, 2001

This report (Appendix 9) provides a summary of results and recommendations from the workshop held in Nanaimo, B.C. Workshop discussions covered a wide array of topics related to the B.C. herring models, supporting data, and current hypotheses of population dynamics and stock structure. Discussions were categorized into the following groups: 1) stock structure, movement, and recruitment; 2) maturation and vulnerability; 3) natural mortality; 4) the spawning index; and 5) biases and interpretation of sampling data. A summary of the issues, discussions, and recommendations is provided.

The Construction of a database of Pacific herring catches recorded in British Columbia from 1888 to 1950

Daniel, K.S., McCarter, P. B. and D. E. Hay. 2001. The Construction of a database of Pacific herring catches recorded in British Columbia from 1888 to 1950. Can. Tech. Rept. Fish. Aquat. Sci. 2368.

A recently published report describes methods used to construct a computer database for Pacific herring catches in British Columbia from 1888-1950. This new database complements the current computer database of herring catches, used for stock assessments, that extends back only to October, 1950. Herring catch records between 1888 and 1950 have been published previously in several documents but have never been entered into a single electronic database. Many pre-1950 catch records have varying degrees of geographic and temporal precision. The report describes these complications and explains solutions. For instance, most of the earlier publications (pre-1950) provide catch summations that have less geographic and temporal precision than post-1950 records. These catch records, however, can provide 'regional' and sometimes, 'statistical area' summations if combined appropriately with the present herring catch database. This information may be useful for a number of purposes, but a specific benefit of including historical catch records in the present database is the extension of mapping capability back into this early period. Construction of this database facilitates mapping of all recorded herring catches from 1888 to the present. Herring catch records can also be mapped in context with other databases including herring tag releases and recoveries, 1936 to 1992 and herring spawn abundance and distribution, 1928 to present.

GENERAL SUBCOMMITTEE RECOMMENDATIONS FOR 2001

The following general recommendations were developed as a result of review of the working papers and Subcommittee discussion:

1. Since annual recruitment contributes a large component (30% to 50%) to the herring spawning biomass, it is important to have an increased understanding of herring recruitment as the key to determining the productivity of stocks and to identifying harvest opportunities. The Subcommittee recommended that the potential for recruitment forecasting for other major stocks continue to be investigated.

2. The Subcommittee recommended that the analysis of juvenile survey data in the Strait of Georgia as a recruitment forecaster be repeated for the 1996 and 1997 surveys after these year classes have recruited in year 2000 and monitored in catch samples for 2 years, in 2000 and 2001.

3. It was noted that stock identification and dispersal remain key biological issues, and that coded wire tagging work initiated in 1999 should be continued in 2002. However, the potential and limitations of the coded wire tagging program should be more clearly identified and evaluated.

4. The Subcommittee reiterated the importance of conducting spawn surveys outside the major stock assessment regions and outside of the current charter programs length / scope. Concern about missing spawn is serious. It was suggested that partnerships with local groups be developed to facilitate acquisition of spawning location and intensity information

5. The Subcommittee reiterated the need for more complete Food, Social and Ceremonial catch data.

6. The Subcommittee endorsed implementing the workshop recommendations.

PROGRESS ON SUBCOMMITTEE RECOMMENDATIONS FOR 2000

Subcommittee recommendations from 2000 are listed below (*Italics*) along with progress reported at the meeting:

1. *The Subcommittee strongly recommended that a PSARC sponsored workshop be convened in 2001 to examine the Age Structured Model, including the data inputs and parameters used in the model. There would be an opportunity to incorporate other biological information, and to examine alternative model formulations. Procedures for estimating uncertainty in the spawning biomass should also be discussed and recommendations made.*

The workshop was held in Nanaimo, June 12-14, 2001. The report resulting from the workshop is appended (Appendix 9).

2. *The Subcommittee also recommended that a meeting be held as soon as possible to develop a framework for the provision of advice that includes presenting uncertainty in parameters and model structure. The intent would be to rationalize the relationship between the different forecasting models and identify a mechanism for quantifying the level of uncertainty contained in the advice.*

Limited progress has been made.

3. *The forecasting of recruitment for the West Coast of Vancouver Island from the summer offshore survey provides an important component to the annual stock assessment. Consequently, it should be incorporated into the routine stock assessment procedure. Since annual recruitment contributes a large component (30% to 50%) to the herring spawning biomass, it is important to have an increased understanding of herring recruitment as the key to determining the productivity of stocks and to identifying harvest opportunities. The Subcommittee recommended that the potential for recruitment forecasting for other major stocks continue to be investigated.*

WCVI forecast is part of routine assessment. Progress has been made to conduct forecasting recruitment for the SG stock.

4. *The Subcommittee recommended that the analysis of juvenile survey data in the Strait of Georgia as a recruitment forecaster be repeated for the 1996 and 1997 surveys after these year classes have recruited in year 2000 and monitored in catch samples for 2 years, in 2000 and 2001.*

Survey data and subsequent recruitment data is being assembled for analysis. A working paper is anticipated in 2002.

5. *It was noted that stock identification remains a key biological issue and that coded wire tagging work and nuclear DNA work initiated in 1999, should be continued in 2001. However, the potential and limitations of the coded wire tagging program should be more clearly identified and evaluated.*

This work is ongoing and working papers are anticipated.

6. *There are emerging remote sensing techniques and technologies that may have some merit. Therefore, the Subcommittee recommended that these continue to be investigated.*

Ongoing. Working paper on video spawn surveys is in preparation.

7. *The Subcommittee reiterated the importance of conducting spawn surveys outside the major stock assessment regions and outside of the current charter programs length / scope. It was suggested that using partnerships with local groups be developed to facilitate further gathering of this information and spawn data acquisition.*

Partnership established in Queen Charlotte Islands. Concern of missing spawn remains.

8. *The Subcommittee reiterated the need for more complete Food, Social and Ceremonial catch data.*

No progress.

9. *In response to a concern about the impact of fishing related mortalities, it was noted that a list of references on the topic may not have been complete and recommended that an annotated bibliography of the impact of gillnet drop out and potential sub-lethal mortalities be prepared for presentation at the 2001 meeting.*

No progress.

Appendix 1. PSARC Pelagic Subcommittee Meeting Agenda, August 29-30, 2001

PSARC Pelagic Subcommittee Agenda	**August 29-30, 2001 Coast Bastion Hotel, Nanaimo Malaspina Room**	
Wednesday, August 29, 2001		
Introductions and Review of Agenda	M. Stocker	8:30-9:00
-Purpose of meeting and outline of process		
-Assignment of Rapporteurs		
P2001-02: Stock assessment for B.C. herring in 2001 and forecast of the potential catch in 2002	J. Schweigert	9:00-14:15
• Break		10:00-10:15
• Lunch		12:00 – 13:00
• Break		14:15-14:30
P2001-03: An evaluation of a recruitment forecasting procedure for Strait of Georgia herring	R. Tanasichuk	14:30-16:00
Thursday, August 30		
Formulation of Advice and Recommendations		8:30-10:00
• Break		10:00-10:15
Review and Finalization of Rapporteur's Reports from Day 1 and 2		10:15-12:00
• Lunch		12:00-13:00
Concluding comments		13:00-13:15
Planning for next meeting		13:15-14:45
• Adjourn		15:00

Appendix 2. PSARC Pelagic Working Papers for August 29-30, 2001

No.	Title	Authors
P2001-02	Stock assessment for British Columbia herring in 2001 and forecasts of the potential catch in 2002	J. Schweigert
P2001-03	An evaluation of a recruitment forecasting procedure for Strait of Georgia herring	R. Tanasichuk

List of Reviewers

Name	Association
Campbell, A.	DFO, Pacific Biological Station
Fu, C.	DFO, Pacific Biological Station
Gazey, B.	W.J. Gazey Research
Houtman, R.	DFO, Fraser River Division

Appendix 3. List of Participants for August 29-30, 2001 PSARC Pelagic Meeting

Name	Association
Alfred, P.	Kwakiutl Territories Fisheries Commission
Chalmers, D.*	DFO, South Coast Division
Chow, S.	Sierra Club of B.C.
Daniel, K.	DFO, Pacific Biological Station
Flostrand, L.	DFO, Pacific Biological Station
Fort, C.*	DFO, Pacific Biological Station
Fu, C.	DFO, Pacific Biological Station
Gazey, B.	W.J. Gazey Research
Gladstone, W.	Heiltsuk Tribal Council
Gordon, L.*	DFO, South Coast Division (Port Alberni)
Greba, L.	Kitasoo Band Council
Groves, S.	DFO, North Coast Division
Hall, D.	Nuu-chah-nulth Tribal Council
Hamer, L.*	DFO, South Coast Division
Hay, D.*	DFO, Pacific Biological Station
Hepples, J.	DFO, South Coast Division
Holkestad, R.	Fishing Vessel Owners Association
Jones, R.	Council of Haida Nations
McCarter, B.*	DFO, Pacific Biological Station
Midgley, P.*	DFO, Pacific Biological Station
Moody, R.	Heiltsuk Tribal Council
Moores, J.*	DFO, National Headquarters
Osborne, J.	Nuu-chah-nulth Tribal Council
Potyrala, M.	DFO, North Coast Division
Redford, A.	Spawn on Kelp Association
Safarik, E.	Herring Conservation and Research Society
Saunders, L.	B.C. Ministry of Fisheries
Schweigert, J.*	DFO, Pacific Biological Station
Stocker, M. (PSARC Chair)	DFO, Pacific Biological Station
Tanasichuk, R.*	DFO, Pacific Biological Station
Ware, D.	DFO, Retired
Webb, L.	Fishing Vessel Owners Association
Wulff, W.	DFO, Pacific Biological Station

* Subcommittee Members

Appendix 4. Criteria for assessment of stock status in 2001: Queen Charlotte Islands

Criteria	Status
1. Data Quality	
a) All catch reported	FSC estimate only
b) All spawn surveyed	Yes, minor spot spawn missed
c) Good sample coverage	Adequate
2. Stock status and trends	
a) RASM-2q	Slight increase overall since 98, near cutoff
b) Escapement Model	Declined 98-00, increasing 2001
c) Spawn indices	Length up, width down, layers up significantly
3. Perceptions of Stock Status	
a) Charter skippers comments	2E stocks rebuilding, but feels a roe fishery in 2002 would be premature. Lots of really small young fish around, both in 2E and 2W
b) Management staff	
4. Recruitment	
a) Age-structured model	96 poor, 97 – 98 average
5. Retrospective Analysis	
a) Consistency	ASM slight tendency to over forecast
6. Forecast Abundance	
a) Profile Likelihood	RASM-2q forecasts average recruitment
b) Recruitment Assumption	**EM** / **RASM-2q**
• Poor	18.31 / 11.97
• **Average**	20.16 / **13.99**
• Good	25.40 / 21.82
7. Additional Information	
a) Size-at-age	Increasing
8. Cutoff:	10,700 tonnes
9. Yield Recommendation	Potential harvest of 2,800 tonnes

Appendix 5. Criteria for assessment of stock status in 2001: Prince Rupert District

Criteria	Status
1. Data Quality	
a) All catch reported	Incomplete - FSC minimal reporting
b) All spawn surveyed	Yes
c) Good sample coverage	Yes
2. Stock status and trends	
a) RASM-2q	Slight increase 97-00, increasing 2001
b) Escapement Model	No trend but increase in 2001
c) Spawn indices	Length width layers increased
3. Perceptions of Stock Status	
a) Charter skippers comments	Kitkatla stocks had improved from previous years, and Big Bay stocks appear to be quite strong
b) Management staff	Stocks looked healthy
4. Recruitment	
a) Age-structured model	97 average, 98 good
5. Retrospective Analysis	
a) Consistency	Very consistent over last few years
6. Forecast Abundance	
a) Profile Likelihood	RASM-2q forecasts poor recruitment
b) Recruitment Assumption	**EM** / **RASM-2q**
• Poor	44.29 / 31.26
• **Average**	47.22 / **34.13**
• Good	56.81 / 42.59
7. Additional Information	
a) Size-at-age	Increasing
8. Cutoff:	12,100 tonnes
9. Yield Recommendation	Potential harvest of 6,830 tonnes

Appendix 6. Criteria for assessment of stock status in 2001: Central Coast

Criteria	Status	
1. Data Quality		
a) All catch reported	Incomplete – FSC some not reported	
b) All spawn surveyed	Complete except some spot spawns	
c) Good sample coverage	Yes	
2. Stock status and trends		
a) RASM-2q	Slight decrease 98-00, decrease 2001	
b) Escapement Model	Decreasing since 98	
c) Spawn indices	Length width layers declining	
3. Perceptions of Stock Status		
a) Charter skippers comments	In general stocks and spawn seemed to be similar to 2000	
b) Management staff	Overall a slight decrease from previous years.	
4. Recruitment		
a) Age-structured model	96-98 poor – average	
5. Retrospective Analysis		
a) Consistency	tendency to over forecast	
6. Forecast Abundance		
a) Profile Likelihood	RASM-2q forecasts poor recruitment	
b) Recruitment Assumption	**EM**	**RASM-2q**
• Poor	28.53	22.89
• **Average**	31.10	**25.38**
• Good	41.73	33.62
7. Additional Information		
a) Size-at-age	Increasing	
8. Cutoff:	17,600 tonnes	
9. Yield Recommendation	potential yield of 5,080 tonnes	

Appendix 7. Criteria for assessment of stock status in 2001: Strait of Georgia

Criteria	Status
1. Data Quality	
a) All catch reported	Yes
b) All spawn surveyed	Yes, with some pressure due to high volume.
c) Good sample coverage	Yes
2. Stock status and trends	
a) RASM	Slight decrease 96-00, increasing 2001
b) RASM-2q	Increasing 96-2001
c) Escapement Model	No change 98-00, increasing 2001
d) Spawn indices	Length slightly up, layers down slightly.
3. Perceptions of Stock Status	
a) Charter skippers comments	All test fishermen thought stocks looked very strong – perhaps better than in 2000. St. of Georgia looked good,
b) Management staff	Stocks showed well – good distribution of fish from NW Bay, Columbia Beach up to Denman / Hornby Is areas. Good spawning at Saanich Inlet, Texada and Pender Harbour
4. Recruitment	
a) Age-structured model	97 – 98 good
5. Retrospective Analysis	
a) Consistency	Slight tendency to over forecast
6. Forecast Abundance	
a) Profile Likelihood	RASM-2q forecasts average recruitment
b) Recruitment Assumption	**EM** / **RASM-2q**
• Poor	89.69 / 81.88
• **Average**	106.54 / **95.49**
• **Average-Good**	106.55 / **103.10**
• **Good**	130.80 / **110.70**
7. Additional Information	
a) Size-at-age	Increasing
8. Cutoff:	21,200 tonnes
9. Yield Recommendation	potential yield of 20,600 tonnes

Appendix 8. Criteria for assessment of stock status in 2001: West Coast of Vancouver Island

Criteria	Status
1. Data Quality	
a) All catch reported	FSC incomplete.
b) All spawn surveyed	Yes, small spawn may be missed.
c) Good sample coverage	Yes
2. Stock status and trends	
a) RASM-2q	Decreasing 97-00, slight increase 2001
b) Escapement Model	Decreasing 97-00, slight increase 2001
c) Spawn indices	Length, width down, layers same
3. Perceptions of Stock Status	
a) Charter skippers comments	Esperanza: looked better than last year, Nootka: poorer than last year, Kyuquot: had a small spawn, Winter Harbour / Klaskish: looked very poor
b) Management staff	Ongrounds presence low. Barkley didn't look great, Clayquot (Sydney and McKay Island) had good spawns, spawn in Hesquiat was disappointing, nothing in Nootka, Esperanza looked good., Area 27 looked very poor
4. Recruitment	
a) Age-structured model	Poor for the fourth year
5. Retrospective Analysis	
a) Consistency	Tendency to over forecast
6. Forecast Abundance	
a) Profile Likelihood	Projecting poor – consistent with the offshore survey
b) Recruitment Assumption	**EM** / **RASM-2q**
• **Poor**	17.60 / **22.44**
• Average	23.73 / 27.86
• Good	39.97 / 44.63
7. Additional Information	
a) Size-at-age	Increasing
8. Cutoff:	18,800 tonnes
9. Yield Recommendation	potential yield of 3,640 tonnes

Report of the BC Herring Stock Assessment Review Workshop, June 12-14, 2001

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Summary

Two independent models are used to forecast stock biomass for B.C. herring. The escapement model uses surveyed egg deposition to estimate escapement from the fishery, which is projected one year forward through application of apparent survival rates and an egg production factor relating egg numbers to spawning biomass. The age structured model is a statistical catch-at-age model that estimates natural and fishing mortality, vulnerability to fishing, and recruitment by fitting these parameters to historical age composition, catch, and spawning index estimates. Stock reconstructions and forecasts from these two models are generally in reasonable agreement, however projections over the last few years for the Queen Charlotte Islands and Prince Rupert District stock assessment regions differ substantially. The divergence of these models represents a dilemma for managers; in some assessment areas the escapement model predicts that biomass is below the Cutoff level used to close the fishery, while predicted biomass from the age structured models is sufficient to permit a harvest.

In response to model discrepancies, the PSARC Pelagics Subcommittee strongly recommended that a workshop be convened to examine the assumptions and application of the age structured and escapement models. Specifically, this workshop would:

- identify and attempt to resolve deficiencies in the current age structured model;
- review the existing fishery and biological data for herring and associated assumptions;
- review the statistical aspects of the ASM and the associated assumptions; and survey alternative model formulations and inherent assumptions.

This report provides a summary of results and recommendations from this workshop, which was held in Nanaimo, B.C., June 12-14, 2001.

Workshop discussions covered a wide array of topics related to the B.C. herring models, supporting data, and current hypotheses of population dynamics and stock structure. Discussions were categorized into the following groups: 1) stock structure, movement, and recruitment; 2) maturation and vulnerability; 3) natural mortality; 4) the spawning index; and 5) biases and interpretation of sampling data. A summary of the issues, discussions, and recommendations is provided.

1.0 Introduction

An annual harvestable surplus for the Pacific herring resource in British Columbia is determined based on a 20% harvest rate of the forecast biomass for five major assessment regions. Biomass is predicted from two different models. The escapement model (EM) uses surveyed egg deposition to estimate escapement from the fishery, which is projected one year forward through application of apparent survival rates to the abundance at age surviving the fishery and an average recruitment assumption. The age structured model (ASM) is a statistical catch-at-age model that estimates natural and fishing mortality, availability to the fishery (maturity), and gillnet selectivity by fitting these parameters to catch at age and spawning index estimates. A detailed description of these models is provided by Schweigert (2000). Stock reconstructions and forecasts from these two models are generally in reasonable agreement, however recent projections for the Queen Charlotte Islands (QCI) and Prince Rupert District (PRD) stock assessment regions differ significantly (Stocker and Radford 2000). Estimates of spawning biomass from the escapement model in these areas have generally been much lower than estimates from the age-structured model. In the case of the QCI data, the escapement model shows a steeply declining trend in biomass from 1997-2000 and a biomass forecast for 2001 that is below the Cutoff level used to close the fishery (10,700 tonnes). In contrast, the age structured model shows an increasing trend over this period and a biomass forecast for 2001 of almost 40,000 tonnes.

The divergence between EM and ASM results for the northern stock assessment areas has been the subject of considerable debate at Pacific Scientific Advice Review Committee (PSARC) stock assessment review meetings. In response to this debate, the PSARC Pelagics Subcommittee strongly recommended that a workshop be convened to examine the assumptions and application of the age structured and escapement models. Specifically, this workshop would:

- identify and attempt to resolve deficiencies in the current age structured model;
- review the existing fishery and biological data for herring and associated assumptions;
- review the statistical aspects of the ASM and the associated assumptions; and
- survey alternative model formulations and inherent assumptions.

This report provides a summary of results and recommendations from this workshop, which was held in Nanaimo, B.C., June 12-14, 2001. The first morning of the workshop consisted of a series of brief presentations summarizing hypotheses, existing data, and the models used to assess B.C. herring abundance. The intent of these presentations was to inform external reviewers attending the meeting, and to stimulate discussion on specific issues. These presentations are summarized in Section 2.0. The majority of the workshop consisted of a series of discussions focused on various aspects of model structure, parameterization, assumptions, and data inputs, and is summarized in Section 3.0. The final half-day of the workshop was used to develop and run alternate formulations of the age-structured model to assess differences in

model predictions and uncertainty estimates. This was a fairly informal session and is briefly summarized in Section 4.0. Workshop conclusions and recommendations are presented in Section 5.0. Appendix 9-A provides a list of workshop participants.

2.0 Summary of Invited Papers

The first morning of the workshop consisted of a series of brief presentations on B.C. herring stock structure, population dynamics, and data bases that were intended to inform external reviewers and stimulate discussion on specific issues. A brief summary of these presentations is provided below. Discussions and questions that were stimulated by these presentations are summarized in Section 3.0.

Review of Herring Biology and the Fisheries

Presenter: J. Schweigert

An overview of basic herring biology, migration patterns, spawning areas, stock structure, and a brief history of the fisheries covering the reduction and present roe fishery was presented. The temporal and spatial patterns of the fisheries and the applicability of surveys of herring spawning grounds as an index of stock size for assessment were highlighted.

Herring Stock Structure - implications for assessments

Presenter: D. Hay

Data on spawning distribution was reviewed relative to the 5 major assessment areas. The distribution of geographic 'clusters' of herring spawning, within and between the assessment areas was reviewed.

1. Southeast Queen Charlotte Islands (QCI) - one main cluster, several smaller;
2. North Coast (Prince Rupert District, PRD) - 2 main clusters (Chatham Sound and Kitlatla Inlet;
3. Central Coast (CC) - 1 main cluster;
4. Strait of Georgia (SG) - several clusters historically but one major cluster at present;
5. West Coast of Vancouver Island (WCVI) - 2 or 3 clusters.

In assessments of previous years, some of the clusters were recognized as separate stocks. Since then, however, the concept of biological 'stocks' of B.C. herring has changed. Presently it is based on a variety of evidence including (1) tagging - which indicates broad mixing within and between assessment areas; (2) genetic analyses - which finds no significant differences among assessment areas, (3) survey data of larvae, juvenile, and adults - which indicates the potential for mixing among areas. Tagging data do not provide the basis for stock identification but results do indicate substantial movements among stocks, as well as evidence for homing at some level. Tagging data, taken in conjunction with genetic data and other data, indicate that there

probably is too much mixing to allow genetic differentiation, but not enough to preclude local adaptation with distinct spawning times, some ecological/population processes (size-at-age), and demographics. On the other hand, there are a number of differences among areas particularly in demographic composition (age frequency) and growth rates among clusters, even from clusters from within the same assessment areas. Therefore, given the apparent lack of any genetic variation but the observed local variation in size and age composition, an outstanding question for age-structured analyses may be related to sampling. To what extent are samples taken from one area (from the catches or from pre-fishery samples) representative of the total region? Is it possible that samples taken from one sub-area are not representative of the area (or 'stock') at large? The answers to these questions require further exploration, particularly as they might have a bearing on reconciliation of the unexplained but large differences in the results of the two assessments procedures used for herring: one based mainly on escapement (or spawning data) and another based on catch- at-age models.

Biological Sampling Database

Presenter: J. Schweigert

The biological sampling database for Pacific herring extends back to the late 1940s and consistent data for all five major herring stocks are available from 1950/51 to present. The frequency and extent of sample collection has varied considerably over time with about 200 seine samples being collected each year prior to 1980 and about 300 per year since then. Sampling coverage was most extensive and consistent in the south, SG and WCVI, while sampling was most erratic in the QCI. Sample size has also varied over time with 100 fish per sample being collected from 1950-55 decreasing to 50 fish per sample from 1956-65. From 1966-1970 an age-length key was used to estimate fish ages. Subsequently, 100 fish per sample have been collected each year. Prior to 1975 samples were obtained only from the commercial fishery apparently on an ad hoc basis. Subsequently, a test fishery has been used to collect one biological sample from each seine test set. In addition, a minimum of 4 samples are taken from each gillnet opening and 10 samples from each seine fishery opening.

The data from these samples are aggregated to obtain key biological parameters for the stock assessment models including age composition, weight-at-age, sex, and maturity information. The biological parameters are then applied to the total catch data to determine the numbers of fish caught from each age class. In general this involves combining the data from all biological samples collected within an area within a year for each gear type but excluding samples of immature fish (>50% age 1 and 2 year olds) during the roe fishery period. Recent analyses indicate that summarizing these data and applying them to total catch at finer spatial and temporal scales has minor impacts on estimates of total fish caught at age.

Estimates of proportion of fish at age over the course of the sampling period each year during the reduction and roe fishery periods indicated a high degree of variability, less so during the more recent period. However, there was no indication of any trend in the proportion of fish at age suggesting that the sampling was representative of the catch and was not biased by younger or older fish joining or leaving the population during the year.

Current information on sampling bias, age-at-maturity, age-specific adult natural mortality and growth

Presenter: R. Tanasichuk

There is concern that the 50-year time series (1951-2001) of herring sampling data contains bias from reduction and early roe fishery samples. Reduction fishery (1951-65) samples were generally collected a number of months before spawning. So, the reduction fishery was an interception fishery rather than a terminal one, which is the case for the current roe fishery. Therefore, fish could have been caught while they were migrating to spawning areas. This would result in uncertainty about which major population a sample should be assigned to. Samples collected during the early roe fishery period (1972-80) were taken by vessels that participated in the fishery, thereby potentially biasing these samples. Tanasichuk (1999) found that catch curves for all major stocks behaved erratically for all five major herring populations until 1980, when samples began being collected by test seiners that were excluded from the fishery. The simplest explanation for this is that samples collected before 1980 were biased and did not reflect the true age composition of the populations. Tanasichuk also found that catch curves for the Central, Queen Charlotte Island and North Coast stocks suggested that fish from these stocks may mature later than age 3, the currently accepted age-at-maturity for B.C. herring. Analyses of scales to estimate age-at-maturity from back-calculated length-at-age are beginning. The goal of this work is to provide an independent estimate of age-at-maturity. This would show either that the age 3 is the age-at-maturity of all B.C. herring, and that the apparent older age-at-maturity could be due to sampling ending before spawning does, or that the northern stocks do mature at an older age.

Age-specific instantaneous natural mortality rates (M) for the West Coast Vancouver Island and Strait of Georgia herring populations were presented. Results showed that M increased with age, and it was suggested that this was a consequence of the surplus energy demand for reproduction (Tanasichuk 2000). Dr. Mark Maunder, International Pacific Tuna Commission, La Jolla, CA, USA, reported a similar observation for tuna.

Information presented on growth consisted of showing the historic and current approach used to forecast weight-at-age for the age-structured model. Tanasichuk and Schweigert (1998) reported that the equation used until 1998 to forecast weight-at-age was overestimating size substantially because of a coast wide trend of declining size-at-age. Weight-at-age time series for all five major stocks were presented to show

that forecasted weight-at-age is now the weight observed during the previous fishing season. This seems acceptable because, although there are time trends in weight-at-age, differences between weight-at-age for two consecutive years are expected to be small.

Spawn Index

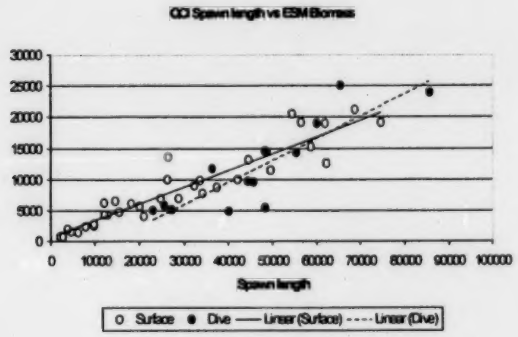
Presenter: J. Schweigert

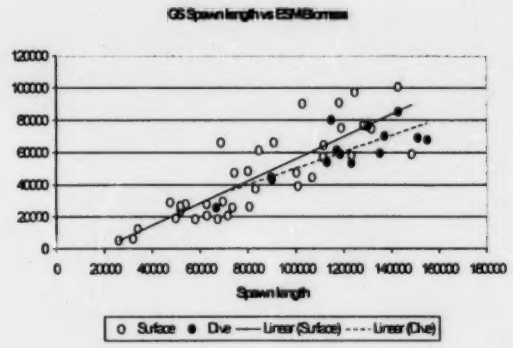
Prior to 1988, a spawn index based on surveys of the length, width, and average number of egg layers deposited in herring spawning beds was determined from surveys conducted from the surface. Subsequently, a greater proportion of the spawning beds have been surveyed by more comprehensive Scuba methods which enumerate the number of layers of eggs deposited on different types of algae within 0.5 m^2 sampling quadrats observed at stations along transect lines set perpendicular to shore across the width of the beds. Surveys of egg deposition on the giant kelp are conducted in conjunction with the Scuba surveys of understorey algae and enumerate plants and fronds to estimate total egg deposition. An important issue is how to combine the data from the various sampling methods to provide a consistent index of spawn deposition. The historical surface spawn data are calibrated to comparable dive data by adjusting the spawn width on a bed by bed basis using the observed median widths from the time series of dive data. Similarly, egg density is determined from the estimate of egg layers using the relationship between the estimated number of egg layers and egg counts from samples collected during several years of experimental dive surveys.

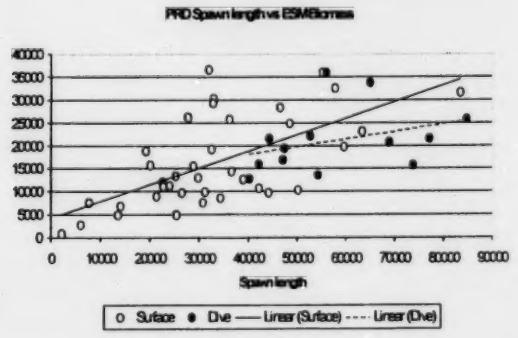
Egg deposition from the various sampling methodologies are then combined to obtain an estimate of the total eggs found in all spawning beds within each stock assessment area each year to provide the spawn index for application in tuning the catch-age model. The total estimated egg deposition is also converted to numbers of spawning adults at age in each area assuming that a tonne of herring produces 1 billion eggs and using the available sampling data to estimate age structure and weight at age. The so-called escapement model is then used to forecast abundance for the coming season.

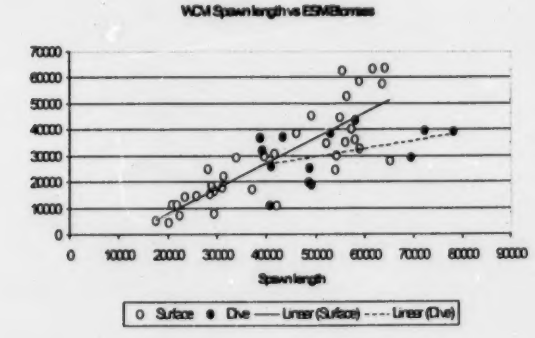
A check on the consistency of the conversion of historical surface spawn data with recent dive data is presented in Figure 1 which compares the estimated escapement model biomass with estimates of total spawn length, a parameter which has been measured consistently by both surface and dive survey methods. It indicates that the spawn index appears to be consistent over the time series in all areas except perhaps on the WCVI in a couple of recent years where the estimated biomass is lower than what might be anticipated given the observed length of spawn.

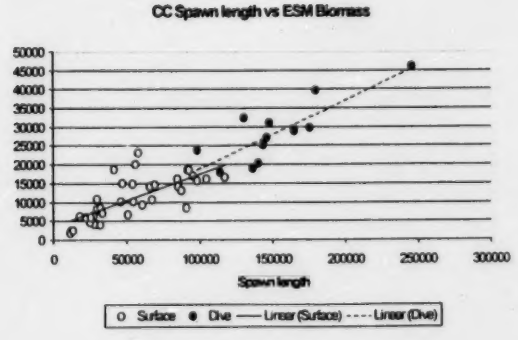
Figure 1. Comparison of escapement model estimates of spawning biomass and spawn length for dive and surface surveys.











Herring Meta-population Dynamics: Significance of straying

Presenter: D. Ware

High fidelity rates (94% to 65%) provide the biological basis for managing B.C. herring populations, because they ensure that most of the adult herring which spawn in one of the 5 major B.C. herring populations spawn in the same population the following year. Straying rates in each population vary from 4% to 35% per year, and appear to increase linearly with the size of the spawning stock up to a maximum rate of about 35%. This hypothesis should be tested by the new herring CWT program. Most of the strays disperse to adjacent populations, so the major populations are linked by an *"isolation by distance"* model of gene flow. If the strays are able to successfully reproduce there should be limited genetic differentiation between the major herring stocks. The genetic work on B.C. herring indicates that this is the case, so *the strays appear to be genetically effective*. More productive populations like Georgia Strait are net exporters of individuals to less productive populations. Consequently, straying increases the persistence time of the less productive components of the meta-population. Straying is important because it recolonizes vacant (or new) spawning habitat. This enables the meta-population to expand its range northward or southward in response to significant changes in climate, and other factors.

On average, during the last 20 years about 25000 tonnes of herring have strayed annually between the five major populations. However, except for Georgia Strait, the estimated average export and import rates were similar. Consequently, straying only added about 1000 to 3000 tonnes of new fish to the WCVI, Central Coast and QCI populations annually. From a stock forecasting and assessment perspective, straying has the largest effect on nearby populations when a large year-class appears. For example, after the exceptionally large 1977-yr class recruited to the QCI population, about 8000 tonnes of herring may have dispersed to the Central Coast and PRD populations. The sudden appearance of this amount of biomass would cause the stock forecast in the Central Coast and PRD populations to be low, and would subsequently cause the age-structured model to underestimate the natural mortality rate (M), and to overestimate M in the QCI population.

Review of the Herring Age-structured Model

Presenter: J. Schweigert

The herring catch-age model is a variant of the model proposed originally by Fournier and Archibald (1982) with some minor modifications. It is based on the Baranov catch equations and estimates the number of fish available at the beginning of each year and following each fishing period. The population model deals with three distinct fisheries: the historic fall reduction or recent food fishery, the spring seine roe fishery, and the spring gillnet roe fishery. The model estimates the projected number of fish for the following year and calculates an estimate of the mature population which has an

expected egg production that is related to the observed egg production, ie. the spawn index. The model estimates a large number of parameters which include the total number of age 1+ fish for each year of the time series and the number of fish at age 2+ to k for the first year. The model also estimates the availability or maturity of age classes 4-6 and the availability of age classes 2 and 3 for each year of the time series except the last year. In addition, parameters for fishing intensity are estimated for each year as are parameters for gillnet selectivity, natural mortality, and the spawn conversion coefficient. The model assumes a multinomial sampling distribution for biological sampling data which are used to determine the catch-at-age from the various fisheries. The effective sample size for the catch-at-age data is determined from the variance in the between vessel samples of age 3+ fish. The model also incorporates a spawn index that is related to the model's estimate of spawn abundance. A maximum likelihood procedure is used to derive parameter estimates using the ADModel software package (Fournier, 1996). The likelihood components for the observed versus true spawn relationship, the observed versus true catch, and from the estimate of age structure are maximized to determine the most probable parameter values.

The results of fitting this model for the five major herring stocks indicate deviations between the model and the spawn index, significantly so for the QCI and PRD stocks (Figure 2) raising the question of what input data or model assumptions are contributing to the observed lack of fit in these areas. One approach was to alter the penalty weights for the spawn index and age composition data and examine the impacts on the biomass estimates. In general, even reductions to one-tenth or increases to ten times the current variance in either the spawn index data or the age composition data had very little impact on the resulting biomass levels and trajectories.

Another approach was to investigate alternative assumptions about natural mortality. Attempts to fit age specific natural mortality through either Tanasichuk's (2000) exponential model or Hampton's u-shaped function have had limited success in improving the fit to the spawn index observations. Similarly, attempts to fit an annual M directly or through a random walk did not markedly improve model fit to the input data series.

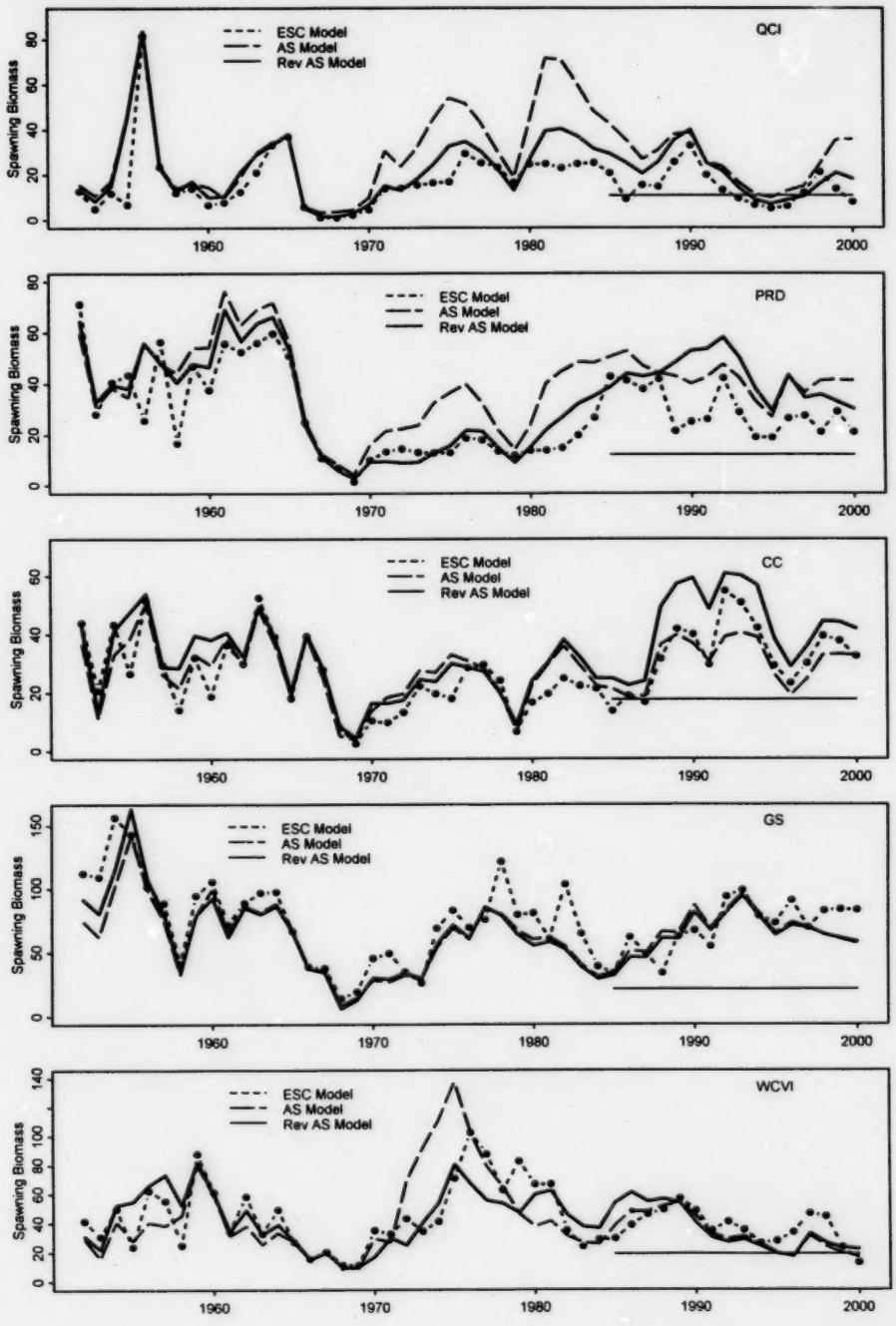


Figure 2. EM and ASM estimates of spawning biomass for the 5 major assessment regions from 1951-2000. Revised ASM incorporates decadal estimates of M. Horizontal line is the cutoff level for each area.

3.0 Summary of Workshop Discussions

Workshop discussions covered a wide array of topics related to the B.C. herring models, supporting data, and current hypothesizes of population dynamics and stock structure. Discussions are categorized into the following groups: 1) stock structure, movement, and recruitment; 2) maturation and vulnerability; 3) natural mortality; 4) the spawning index; and 5) biases and interpretation of sampling data. A summary of the issues, discussions, and recommendations is provided below.

3.1 Stock Structure, Movement, and Recruitment

Stock Structure

BC herring assessments are currently conducted on 5 stock units:

Strait of Georgia (SG);
West Coast of Vancouver Island (WCVI);
Central Coast (CC);
Prince Rupert District (PRD); and
Queen Charlotte Islands (QCI)

Genetic analysis completed to date shows limited variability between stocks although it was recognized that there is phenotypic variation between stocks that is not captured by the genetic analysis and that possibly represents local adaptation. There is also strong evidence of substantial straying rates between stocks from the tagging data. Discussions at the workshop focused on the possibility of applying the assessment procedures at a finer scale by further subdividing the stock structure, or alternatively, at a coarser scale by aggregating some or all of the stocks.

Although participants in the workshop briefly considered the biological basis for other stock structure configurations, this topic was not pursued because it was felt to be parenthetical to the main objective of the workshop: that is, an analysis of the stock assessment models. The workshop did briefly discuss and consider, however, the merits of pooling data in different ways - but this was not done in the context of having implications for 'biological stocks'.

From the perspective of the assessment models there are advantages and disadvantages to different aggregations The two aggregation schemes that were discussed combined all stocks into a single unit (termed the 'roll-up' stock), or into two units for southern (WCVI + SG) and northern regions (CC + PRD + QCI). Aggregation of stocks potentially reduces the effects of migration on stock-specific model applications. For example, immigration of fish from one assessment region to another will result in overestimates of recruitment and/or underestimates of natural mortality. However, this bias can be reduced if stocks are aggregated to the point where migration between the larger stocks becomes inconsequential. Another benefit of

aggregation is to reduce the effects of incorrect assignment of catch and age composition due to interception of migrating stocks during the reduction fishery period.

The disadvantages of combining stocks were also discussed. Uncertainty in model parameter estimates would not necessarily be improved because combining data potentially reduces temporal variation in biomass over time due to asynchronous variation in recruitment between some stocks. Variation in biomass is critical for improving estimates of q and M that in turn lead to greater certainty in stock size forecasts. In addition to this disadvantage, allocation of quotas among the five regions would be problematic if only one (coastwide) or two (North and South Coast) stock size estimates were available. It was argued that quotas could be allocated among assessment regions based on the relative proportions of estimated post-fishery spawning biomass from the previous year(s). However, recognition of differences in productivity and temporal trends in recruitment among stocks, and difficulties in assigning and imposing closures when forecast stock sizes were below the Cutoff level, favored the continued use of the current 5 unit stock structure.

A meta-analysis approach to stock assessment modelling was endorsed by all participants. This method requires that the catch-at-age model be run simultaneously for all stocks and that certain model parameters, such as the instantaneous mortality rate (M) or vulnerability parameters, be estimated jointly across stocks. This approach offers the advantage of allowing for differences in productivity and recruitment trends among stocks, while possibly reducing uncertainty through common estimation of key model parameters. Note that a meta-analysis approach can be implemented with or without a meta-population model that explicitly models movement among stocks through incorporation of the tagging database.

Incorporating Effects of Movement Between Stocks

The analysis presented by D. Ware and D. Hay provided convincing evidence that there can be a significant exchange of fish between the 5 stocks used in the current stock assessment procedure. The possibility of incorporating a movement component into the existing ASM was endorsed by most participants. This meta-population model would simulate the five regional stock assessment groups in a single framework and allow exchange of individuals between stocks. The extensive B.C. herring tagging database would have to be directly incorporated into the modelling framework so that movement parameters, mortality rates, catchabilities, fishing mortality, and other parameters would all be estimated simultaneously. This integrated framework offers two major advantages. First, the framework ensures consistency in common parameter estimates between the population model and a tagging-movement model. More importantly, the model would lead to improved interpretation of movement patterns. Current estimates of movement between stocks do not account for different harvest rates among regions over time, a dynamic that is acknowledged to have an impact on estimates of fidelity, straying, and immigration rates obtained from the tagging data. By incorporating the tagging data directly into a model that reconstructs historic harvest

rates and population dynamics, estimates of movement parameters would likely be improved, or at the least would be internally consistent with assumptions used in the stock assessment process.

Development of a meta-population model would be a considerable undertaking. While templates of integrated movement and catch-at-age models exist (e.g. Maunder *In Press*), the model is a major departure from the existing ASM and requires the synthesis and analysis of a very large tagging database consisting of over 1.6 million tags and over 43,000 recaptures (Hay et al. 2001). As the resolution of these data varies over time and space, a considerable amount of effort would be required to filter and analyze the data prior to incorporation into a model. Although not a prerequisite, the model would also likely commit the Department of Fisheries and Oceans to continued collection of tagging data. Funding to support such an effort in the long term is highly uncertain. Finally, there is no guarantee that this model will lead to improved forecasts although it would certainly represent a major step forward as a research tool that integrates existing data and hypotheses of herring population dynamics.

The details of the meta-population model structure were not discussed in depth, although a few structural elements were considered. The model would likely need to incorporate a function relating straying rate to spawning biomass as data presented by D. Ware demonstrated increased straying at higher stock biomass. The model would also need to account for the differences in exchange rates among stocks as a function of distance between stocks. D. Hay's analysis demonstrated that movement rates between adjacent stocks are higher than rates between stocks that are further apart.

Recruitment

The current catch-at-age model used in the B.C. herring assessments does not include any relationship between spawning biomass and recruitment although an earlier version did include a Ricker S/R function that could be easily re-introduced. D. Ware presented results of analyses suggesting that a 'hockey stick' pattern between stock and recruitment during warm oceanic regimes was appropriate whereas a Ricker function fit the available data best during colder oceanic regimes. There was a consensus among workshop participants that a stock-recruitment relationship should be incorporated into the ASM. It was emphasized that the estimation of the stock and recruitment relationships should be done inside the stock assessment model. This offers two advantages. First, any assumptions made to generate the stock and recruitment data (e.g. sex ratio, fecundity, size-at-age) would be internally consistent with those used in the age-structured model for the stock assessments. Second, uncertainty in the stock and recruitment relationship could be easily incorporated into the estimates of uncertainty in forecast stock size. In addition, penalty functions used to bound interannual variation in recruitment anomalies in the stock assessment model could be conditioned based on the process variation around the stock and recruitment relationship.

The incorporation of physical variables, such as sea surface temperature, into the stock and recruitment analysis was discussed. Such variables would be included in the modelling process as another time series of information (like catch-at-age or spawning biomass) but would be used to predict a component of the annual recruitment anomalies.

3.2 Maturation and Vulnerability

Maturation

The issue of whether all herring mature at age 2+ as indicated by histological information or whether a significant proportion mature later as suggested by the age composition data and catch curve analyses was discussed at length. It was suggested that the issue of maturity and vulnerability could be confounded in the current ASM implementation. One approach to this question would be to fix the maturation schedule based on the histological information and then estimate vulnerability parameters for the seine fishery to investigate the confounding of these processes.

Vulnerability

The current version of the ASM assumes that vulnerability for ages 3+ to 5+ is constant over time. While this is probably true for seine gear, changes in gillnet mesh sizes and hanging ratios have likely affected the vulnerability of these age-classes over the course of the time series. Three options for examining these vulnerability changes were discussed. One option is to perform a cohort analysis using the gillnet fishery data to solve the catch equations and estimate selectivity changes over time directly. The second option was to allow the ASM to estimate age-specific vulnerabilities for each year of the simulation, or at least different vulnerabilities for a few gillnet vulnerability stanzas. A third option is to model selectivity changes explicitly in the ASM by developing relationships between vulnerability and gear types, and to fit separate parameters for gillnet selectivity during different time periods that are expected to have changing vulnerabilities. The cohort analysis could be conducted for a couple of areas where sufficient gillnet catch data exists. The second option would result in a considerable increase in the number of parameters to be estimated and could increase uncertainty estimates in forecast stock sizes. The third approach appears to be most productive and could be conducted in conjunction with the cohort analysis to identify time periods of changing vulnerability.

The assumption of complete vulnerability for ages 6+ was also reviewed at the workshop. There was concern that large fish could be less vulnerable to gillnet capture depending on mesh size, however this was not considered a significant issue.

The current ASM uses catch equations that model fishing and natural mortality as a continuous process even though these two processes are only coincident for a small period during the reduction fishery. The possibility of switching the catch equations to

the form that models instantaneous removals was considered to be a minor undertaking and it is expected that it would have little or impact on the results.

3.3 Natural Mortality

The ASM jointly estimates the instantaneous natural mortality rate (M) and the catchability coefficient (q, relating model predicted biomass to the spawning index, i.e. 'q' in eqn. 3.3 of Schweigert 2000). As these parameters are confounded, there is considerable uncertainty in estimates of M. At the workshop, two approaches for improving estimates of M were discussed. The preferred method was to incorporate tagging information into the ASM. This approach would help separate catchability and mortality effects by directly modelling the survival of tagged cohorts over time. The second suggestion was to employ a meta-analysis where M is jointly estimated across stocks.

Participants at the workshop discussed the possibility of incorporating more detail in the estimation of M in the ASM, either by allowing M to vary annually, and/or allowing it to vary with age. The former option greatly increases the number of parameters in the model. A reliable estimate of M is already difficult to achieve with available data because there are no independent estimates of q or migration rate. Estimating M for each year would be even more difficult and subject to greater confounding. One compromise that was identified was to estimate M separately for particular time periods (e.g. 1951-1976, 1977-1988) that reflect periods of good and poor ocean conditions. Unfortunately, these stanzas are coincident with major changes in the fishery and spawning surveys, so it will likely be very difficult to untangle climatic effects on M from these other factors.

There was some discussion of modelling a 'U' shaped function in age-specific natural mortality rates allowing for higher rates for immature and senescent fish, and lower rates for mature fish. Alternate approaches for doing this included:

- estimation of parameters for a parabolic function;
- 'Hampton's' method, which allows independent estimation of M for each age with smoothing penalties to avoid large changes in M between successive age classes and extreme deviation from the mean; or
- Some combination of these methods, where M for younger ages is estimated independently (with a smoothing function) and M's for older ages are estimated by parameterizing a parabolic relationship.

3.4 Spawning Index

The spawning index provides an estimate of the biomass of spawners escaping the fishery based on surveys of the spawning areas. It is used as the abundance index to tune the ASM by assuming a linear relationship between the predicted spawning stock

biomass from the ASM (R from eqn. 3.3 of Schweigert 2000, I=qR) and the spawning index (I).

There was a lengthy discussion at the workshop about the strengths and weaknesses of the spawning index and what it actually represents. All participants felt that variation in age-at-maturity, sex ratios, and fecundity would have little impact (<5%) on the estimated spawning index. Some participants felt that the index provided a more robust prediction of next year's biomass than the ASM predictions. Initially, it was proposed that the spawning index could be used as an absolute measure of abundance in the ASM (i.e. assume q=1 in I=qR) reducing uncertainty in the instantaneous natural mortality rate and the forecast stock size. However, during the discussions, it became clear that there is little basis for the assumption that q=1 and an alternative model for q was suggested:

$$OED = PS\,(TE - TE^{*}EL),$$

where,

OED = observed egg deposition in the assessment area,
TE = total eggs present in the assessment area,
EL = egg loss rate due to predation and drift,
PS = proportion of available eggs surveyed.

Participants estimated PS>0.9 and EL<0.5, resulting in a minimum estimate of q of 0.45 and a most likely estimate of q of around 0.8. These estimates were used in a later model gaming session (Section 4.0) to evaluate the effect of using a prior probability on q to reduce uncertainty in forecast stock size.

Three alternatives for incorporating the spawning index into the ASM were identified. First, the computation of the index could be done within the ASM. The main advantages of such an approach include: 1) all information contained in creating the index is available to the stock assessment model parameter estimation procedure; 2) uncertainty in the standardizing process is automatically included in the parameter estimates of the stock assessment model; and 3) the methodology is flexible, allowing for the inclusion of many different structures for standardizing the index data and for modelling the error structure (Maunder 2001). However, this would require a complicated pre-processing of the raw spawn observations within the ASM to derive the spawn index and it was felt that this might be an unrealistic undertaking. Second, estimation of q in the ASM could be made stanza-specific to reflect differences in efficiency between surface and Scuba egg survey periods and this has been done in the past with a minor impact on model results. Finally, a non-linear function could be used to estimate q based on spawner biomass (i.e. $q = aB^{b}$, where B is spawner biomass, and a and b are parameters). Participants suggested that both density dependent egg production and higher egg loss rates at greater spawner densities could result in hyperstability between the spawner index and spawner biomass. This dynamic was supported by the discrepancy between age composition and spawning

index data from the late 1970's in QCI. The age composition data indicated a large recruitment event in 1977 moving through successive ages in subsequent years. In contrast, the spawn index remained relatively stable over this period even as the cohort left the population.

The possibility of using larval and juvenile survey data as additional tuning indices for the ASM was discussed. Participants noted that the correlation between these indices and the spawning index is weak. While it is possible that this poor correlation could be due to density dependent effects or errors in the spawn index, most participants felt that the limited effort on larval and juvenile surveys probably resulted in very high sampling variance. In addition, because larval and juvenile survey time series are typically less than 5 yrs, it was felt that there would be little utility in incorporating these data into the ASM tuning procedure.

3.5 Sampling Data

Discussions at the workshop frequently focused on the interpretation of the sampling data used in the stock assessment procedure. A number of the exchanges focused on issues related to age composition and catch estimates. A summary of these discussions is provided below:

Adequacy of Age Composition Data - Reduction vs. Roe Fishery Periods

There was considerable debate about the effects of fishery changes on the estimated age composition. During the reduction fishery period, fishing occurred from November to March, in contrast to the roe fishery period, where fishing is concentrated during the spawning period (March-April). Age composition samples taken from the roe fishery reflect the age composition of spawners in that assessment region, while samples taken during the early months of the reduction fishery reflect a large proportion of migrating fish, some of which may be destined to spawn in other assessment regions. Therefore, it is possible that some age composition samples taken during the reduction fishery may include immature fish, and the age composition for some regions (e.g. WCVI) may be contaminated with fish destined to spawn in other areas (e.g. SG).

The analysis presented by J. Schweigert did not show any trends in age composition with respect to sampling date and year. However a more formal statistical analysis of these data may be helpful. If the analysis does reveal a significant effect of the fishery type on age composition (or a significant season-fishery interaction term), two approaches were suggested. The age composition data could be filtered prior to inclusion in the ASM to eliminate data from early winter months (Nov.-Dec.) that may over represent immature fish and fish destined to spawn in other assessment regions. However, these samples are probably very representative of the catches taken on the migrating stocks. Alternatively, the reduction fishery period could be sub-divided into Nov.-Dec. and Jan.-Mar components with separate age-specific vulnerability estimates within a meta-population analysis to deal directly with the issue.of interception of migrating stocks.

Age Composition - Test vs. Commercial Seine Samples

Age composition data from test and commercial seine catches for the roe fishery period are combined prior to inclusion in the ASM. Some workshop participants were concerned that combining these data could bias age composition estimates. The test fishery data may not reflect the age composition of the catch because samples are taken before the commercial opening and may contain a higher proportion of smaller fish. Samples taken later in the test fishery may not be random because the test fishery is monitoring the maturity and quality of fish that will be harvested. The analysis of age composition by sampling date and year presented by J. Schweigert does not indicate any trends in age composition over the course of the test fishery but a more formal statistical analysis of the data may be warranted. If significant differences between test and commercial fishery age composition estimates are found, then some test fishery data could be excluded from the ASM analysis.

Inconsistency in Ageing Errors

Participants suggested that there have probably been changes in precision and bias of age estimates over time due to changes in techniques and the experience of laboratory staff. In particular, concern was raised over age estimates collected during the early years of the roe fishery. The extent of this error could be evaluated by examining the archived scales that are available from 1976 and recomputing the age composition, however this would be a very time consuming analysis. An alternative approach would be to down-weight the age composition component of the objective function for the period of concern. The third alternative which is currently used in the ASM is to pool age groups older than 5+. Participants did not feel that the potential bias from ageing errors would have significant effects on the model. Ageing errors were expected to be most common for older fish (ages >5+) that represent a relatively small proportion (<20%) of the total sample.

Computation of Proportions at Age

Participants requested clarification on the conversion of total catch to numbers at age. H. Stiff verified that the following calculations were correctly determining numbers of fish in the catch:

$$N_T = \frac{B}{\sum_{a}^{a=k} P_a * W_a}$$

$$N_a = N_T * P_a$$

where,

N_T = total number of fish in the catch,

N_a = numbers of fish at age a in the catch,
P_a = proportion of fish in the sample of age a,
B = total biomass of catch,
W_a = mean weight at age a,
k = maximum age.

It was noted that errors in age composition (P_a) due to ageing errors or biases would impact the estimates of N_a.

Effective Sample Size for Multinomial Variance for Age Composition Data

In the ASM analysis function minimization occurs based on the likelihood components associated with the catch, spawn, and proportion at age estimates. In the minimization these terms are weighted by their respective variances. Incorrect estimation of the variance for the age composition component could lead to an under-or over-representation of this term in the overall objective function. Schweigert (2000) describes the procedure to compute the variance terms for age composition data, adapted from Fournier and Archibald (1982). In brief, the variance term for the proportion-at-age is computed assuming a multinomial distribution and is dependent on the sample size. The procedure does not use the actual number of fish aged or the number of catches sampled as the sample size because the among-vessel variation in age composition samples is related more to spatial and temporal patterns in fishing than to the number of loads sampled. Instead, a theoretical sample size is computed based on the variance in proportions of age 3+ fish, and this estimated sample size is then used in the multinomial equation that predicts the sampling variance for the age composition data.

There was some discussion of whether or not it was necessary to adjust the effective sample sizes rather than applying the observed sample size directly but there was insufficient time to evaluate this further at the workshop. It was suggested that this effect could be tested directly by using the observed sample sizes in the analysis.

Misreporting of Catches

It was recognized that changes from a reduction to a roe fishery have likely reduced incorrect assignment of catches to particular assessment areas. During the reduction fishery period, catches in a particular assessment area could consist of fish destined to spawn in that region as well as migrating stocks destined to spawn in other areas. The ASM assumes that all catch in an assessment region is destined to spawn in that area. This issue could be assessed by modelling movement of fish between assessment regions using a meta-population model (See *Incorporating Effects of Movement Between Stocks* of Section 3.1).

In addition to misreporting caused by migration, there may be deliberate misreporting of catch locations by some fishers, but the extent of this misreporting, or changes in misreporting rates over time, is unknown. It was acknowledged that this problem is

likely worse for earlier periods, and could be accounted for by reducing the weighting on earlier data in the modelling process.

Effort Data

The feasibility of incorporating effort data into the ASM to reduce uncertainty in fishing mortality estimates was briefly discussed. Participants agreed that major changes over time in technology and the way fisheries have been conducted make the effort data very unreliable as an index of fishing mortality rates.

Forecasts of Weight-at-age

Forecasts of biomass from the ASM are based on the predicted numbers-at-age for the forecast year multiplied by the weight-at-age observed in the current year. There was some concern that inter-annual differences in weight-at-age data could result in larger forecast errors for the projected biomass. J. Schweigert presented plots of weight-at-age over time that showed a long term decline, but relatively consistent weights between adjacent years. Participants agreed that differences in weight-at-age between adjacent years would not have significant impacts on the biomass forecasts.

4.0 Summary of Model Development Session

Workshop participants were able to examine alternate model formulations through presentations made by the external reviewers. Results from these presentations and model gaming sessions were considered very preliminary given the brief amount of time spent developing and checking the models.

F. Funk presented a simple catch-at-age analysis in an Excel spreadsheet using data from WCVI and QCI. This model was fit to catch-at-age and spawn survey data for the entire period of record and for the roe fishery period separately. The model simulated gillnet and seine fisheries separately, allowing for different age schedules of vulnerability that were not allowed to vary over time. The model also allowed for age-specific estimates of natural mortality rate. The catchability coefficient to scale egg deposition predicted by the model to the observed spawn index was also estimated but did not vary over time.

F. Funk's presentation was informative because the development of the model in a spreadsheet environment made the model assumptions and structure more transparent to participants who do not routinely develop and run stock assessment models. His analysis focused on the effects of the weighting factors used in the objective function to scale the sums of squared deviations for two of the three components of the objective function (proportions-at-age and egg deposition) used in the ASM. The analysis clearly showed that in areas where the spawning index and age composition data are in agreement, the weighting values had little impact on the predicted time series of biomass. The analysis of the QCI data contrasted this result. For example, an increase in the weighting (decreasing the variance) for the age composition component of the objective function resulted in model predictions that more closely resembled the age composition trend rather than the spawn index trend. The analysis was instructive in highlighting the breakpoints in the sensitivity to variance estimates used in the objective function.

J. Ianelli and M. Maunder developed alternate models using AD Model Builder for individual assessment regions and for all regions combined (hereafter referred to as the 'rollup' stock) using data for the roe fishery period only. The catch and age composition data used to fit their models combined gillnet and seine fisheries and could be run on a stock-by-stock basis or as a meta-analysis where a single value of instantaneous mortality was estimated across all five stocks. Briefly, a number of simplifications were implemented:

1) The catch was removed instantaneously each year after 95% of the natural mortality had occurred;
2) All of the catch was taken at this instant (from all three "periods" from the old assessment) and only data from 1983 and onwards was used.
3) The spawning index data was fit assuming a standard deviation of 0.20 (log-scale) for each year.

4) The age-composition data was assumed to follow a multinomial distribution with an annual sample size of 100.

The analysis presented by J. Ianelli and M. Maunder highlighted the problem of confounding between q and M. Nearly equivalent fits to the time series of biomasses could be achieved by high values of q and M, or low values of q and M, regardless of the length of the time series used. Consequently, predictions of spawning biomass in 2001 were highly uncertain. Running the model on the entire period of record provided more precise estimation of q because of the stronger contrast in stock size and the spawn index, however potential biases in age composition from sampling during the reduction fishery could offset this benefit.

To provide more precise estimates of 2001 biomass, a prior probability of q was developed based on input from workshop participants (Fig. 3, see Section 3.4).

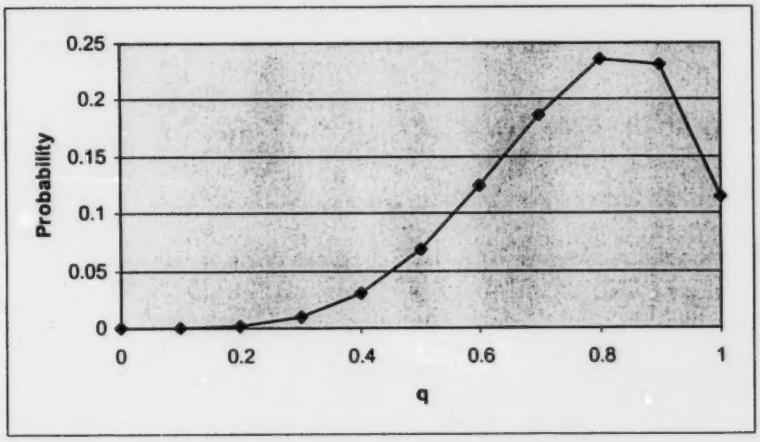


Figure 3. Prior probability distribution of spawning survey catchability coefficient (q) used in AD Model Builder gaming session.

Application of this prior in the objective function resulted in a much tighter distribution of forecast biomass (Fig. 4).

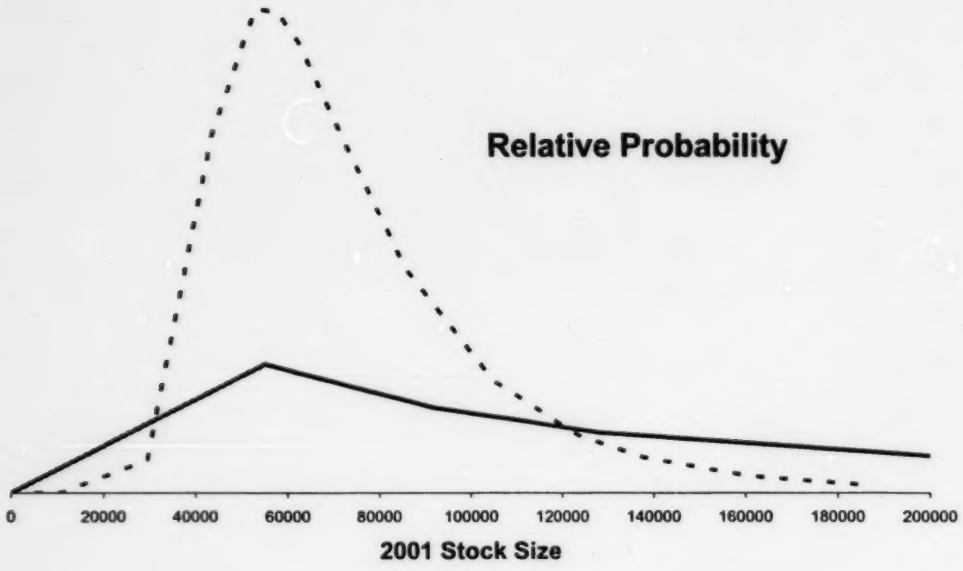


Figure 4. Profile-likelihood approximation to the posterior distribution of the 2001 projected stock size with a prior distribution assumed for the herring spawn-index survey (dotted line) and without a prior distribution in the fitting process (solid line).

The meta-analysis demonstrated the effects of estimating a common M across all stocks. When all regional stocks were combined into a single stock, the biomass trajectory was relatively stable and quite uninformative in terms of estimating q or M. Participants hypothesized that this pattern could be the result of asynchronous patterns in recruitment among regions. The roll-up analysis was perceived initially as potentially useful for reducing problems associated with migrating stocks. However, this potential benefit was possibly offset by a less informative trajectory when data from all stocks was combined. Another interesting result of the analysis showed that estimates of natural mortality were significantly lower when the age-composition data were aggregated from age 6 and older compared to using the data for individual ages up to age 9.

5.0 Conclusions and Recommendations

The review and discussion of the herring catch-at-age model and input data series provided the basis for the development of alternative model formulations but which yielded very similar biomass estimates and trajectories to the ASM. Unfortunately, the limited time frame did not permit detailed examination and testing of all model features and assumptions. However, there does appear to be considerable value in pursuing a combination of the simpler spreadsheet approach demonstrated by F. Funk and a simpler version of the existing ASM as presented by J. Ianelli and M. Maunder. The recommendations below include the need to address some of these issues within the current ASM as well as providing direction and scope for future research to improve assessment model performance including the development of estimates of variability for decision making and management.

Recommendations:

1) Meta-analysis of all stocks as a unit should be investigated as a basis for improving the current stock assessment model and perhaps some of the parameter estimates.

2) Meta-population modelling research should be continued to determine whether relationships between stock movement and abundance can be derived that could be incorporated into a future coastwide migration model.

3) A stock-recruitment function should be re-introduced into the catch-at-age model as a basis for forecasting future abundance, evaluating harvest rate strategies, and as a basis for determining reference points.

4) Confounding of maturity and fishery selectivity should be investigated by fixing the maturity schedule based on available histological data and separately estimating gear selectivity patterns.

5) Cohort analysis of gillnet catch data should be conducted to test for changing selectivity over time resulting from changes in fish and mesh size.

6) Alternative formulations for the relationship between the spawn index and modelled egg production should be assessed.

7) Biological sampling data should be reviewed to ensure that samples from the commercial and test fisheries are comparable over space and time.

8) The effective sample sizes used in the age composition likelihood component should be reviewed and assessed against alternative formulations.

9) The confounding of the natural mortality and spawn conversion parameters needs to be addressed. Options for fixing one of these parameters within a Bayesian assessment framework should be investigated.

6.0 References

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Appendix 9-A. List of Participants for June 12-14, 2001 Herring Stock Assessment Model Review Workshop

Name	*Association*
Fort, C.	DFO, Pacific Biological Station
Funk, F.	Alaska Department of Fish and Game, Juneau
Hamer, L.	DFO, South Coast
Hay, D.	DFO, Pacific Biological Station
Ianelli, J.	National Marine Fisheries Service, Seattle
Korman, J. (rapporteur)	Ecometric Research Inc.
Maunder, M.	Inter-American Tropical Tuna Commission, La Jolla
McCarter, B.	DFO, Pacific Biological Station
Midgley, P.	DFO, Pacific Biological Station
Palermo, V.	DFO, Vancouver
Saunders, M	DFO, Pacific Biological Station
Schweigert, J.	DFO, Pacific Biological Station
Stocker M. (chair)	DFO, Pacific Biological Station
Stiff, H.	Database Consultant, Nanaimo
Tanasichuk, R.	DFO, Pacific Biological Station
Thomas, G.	DFO, South Coast
Ware, D.	DFO, retired / Consultant